Experiment No.: ***07***

Experiment Name: ***Development of Generalized Specific Energy and Specific Force Curves***

Experiment Date: ***30-07-2022***

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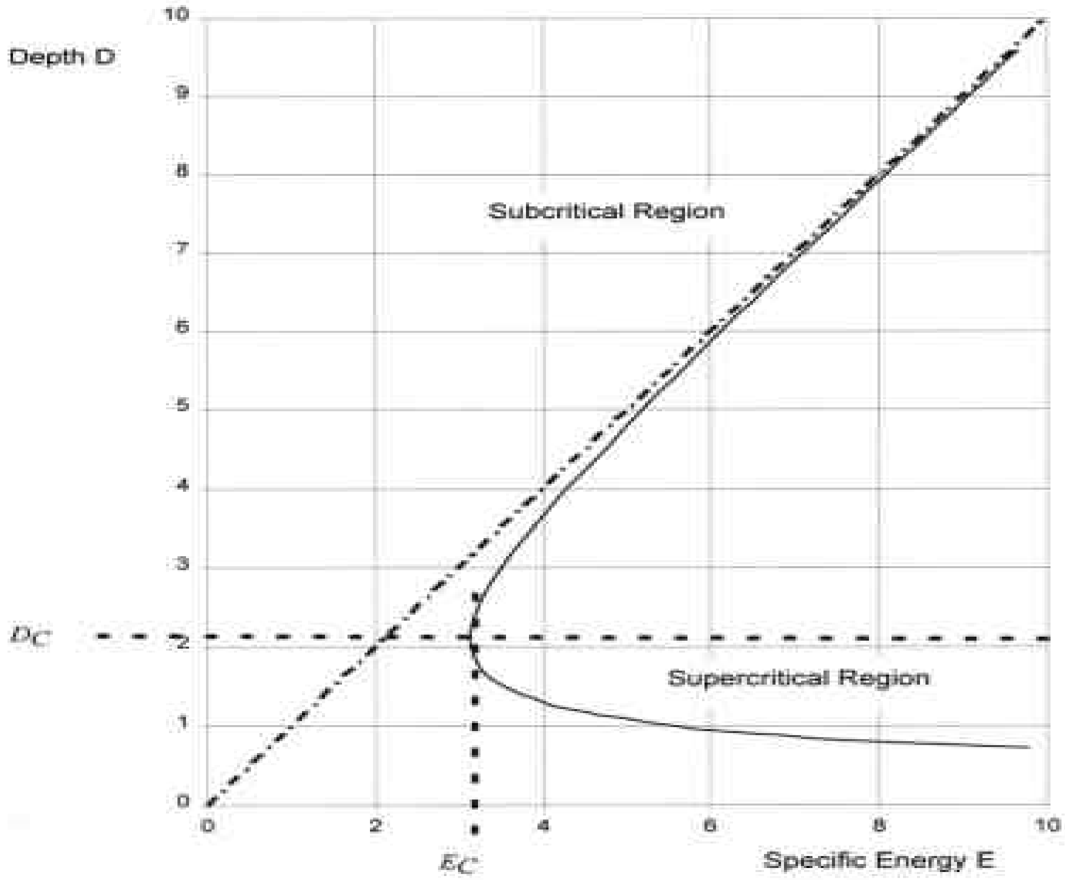

Depth D
Subcritical Region
Supercritical Region
D_C
E_C
Specific Energy E
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10

1. Introduction

The concept of specific energy and specific force is extremely useful in the solution of many problems in open channel flow. This experiment deals with the development of generalized specific energy and specific force curves. These curves are useful in determining the state of flow in a channel, i.e. whether the flow is critical, subcritical or supercritical. Flow is critical when the Froude number is equal to unity. When the depth of flow is above the critical depth, the subcritical state of flow exists in the channel. When the depth of flow is below the critical depth, the supercritical state of flow exists.

Also, the critical state of flow gives us several important conditions, such as, the specific energy and specific force are minimum for a given discharge, the discharge is maximum for a given specific energy and so on. All these conditions are used in designing the various types of transitions and in controlling the flow using different control structures, for example, in determining the height of a weir, the width of a flume, opening of sluice gate, etc.

2. Theory

Specific Energy

Specific energy is defined as the energy per unit weight of water at any section of a channel measured with respect to the channel bottom. If the total energy at any section is given by

$H= z+y+V^2/2g$ ………………………………………………………………….1

then the specific energy at any section of a channel is obtained by putting $z = 0$ as

$E= y+V^2/2g$……………………………………………………………………….2

Since Q = Av, Eq.(2) can be written as

$E=y+Q^2/(2gA^2)$ ……………………………………………………………3

For a rectangular channel, A = by. So Eq. (3) can be written as

$E=y+Q^2/2gb^2y^2$ ………………………………………………………......4

Specific Energy Curve

For a given channel section and discharge, the specific energy is a function of the depth of flow. When the depth of flow is plotted against the specific energy, a specific energy curve is obtained. This curve has two limbs CA and CB (Fig.1). From Eq. (4), when y tends to 0 (zero), E tends to infinity, So the limb CA approaches the horizontal axis asymptotically towards the right. Also, when y tends to infinity, A tends to infinity, so that $V^2/2g$ tends to 0 (zero) and E tends to y, which implies that the limb CB approaches the E = y line (line OD) asymptotically. As the slope of the E = y line is 1, so it has an inclination of 45 degree with the horizontal axis and passes through the origin.

The specific energy curve (Fig.1) shows that, there are two possible depths for a given value of E, the low stage y1 and the high stage y2, which are the called alternate depths.

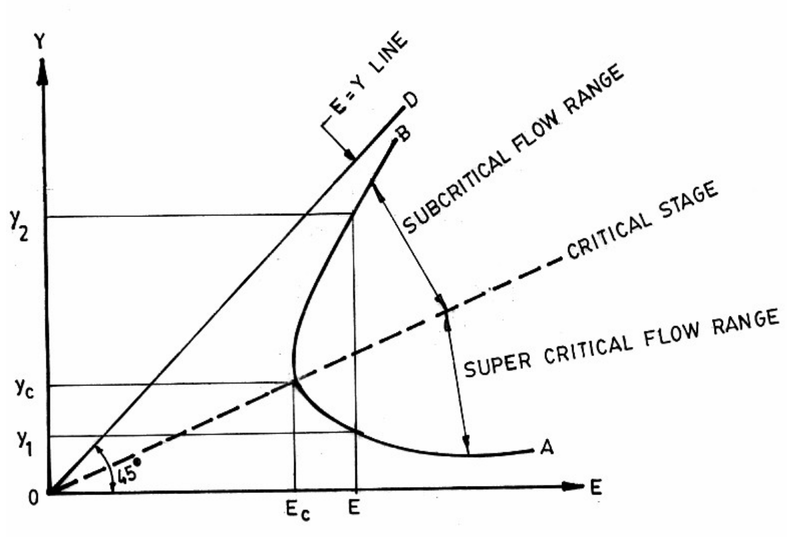

Fig. 1 Specific-energy curve

Differentiating Eq.(3) with respect to y and simplifying, we obtain

$dE/dy= 1-v^2/gD$

Where, D is the hydraulic depth.

At point C, the specific energy is minimum

$dE/dy=0$ so that $v^2/gD=1$ or, $Fr^2=1$ Hence $Fr = 1$

This condition represents the critical state of flow. At this condition, the two alternate depths apparently become one which is known as the critical depth yc. When the depth of flow is greater than yc, the velocity of flow is less than the critical velocity for the given discharge and hence the flow is subcritical. When the depth of flow is less than the critical depth, the flow is supercritical. Hence, y1 is the depth of supercritical flow and y2 is the depth of subcritical flow.

Generalized specific energy curve

If the discharge changes, the specific energy curve also changes, i.e. the curve moves to right if the discharge is increased and vice versa. In order to develop a generalized specific energy curve, i.e. to use one specific energy curve for different discharges, the curve is to be made dimensionless with respect to the critical depth, as the critical depth yc is constant for a given discharge. So dividing both sides of Eq. (4) by yc and after simplification, we obtain

$E/y_c = y/y_c + 1/2*(y_c/y)^2$ ……………………………………………………………5

Equation (5) is the generalized form of the relationship between specific energy and depth of flow in which each term is dimensionless. The plot of this equation is shown in Fig. 2.

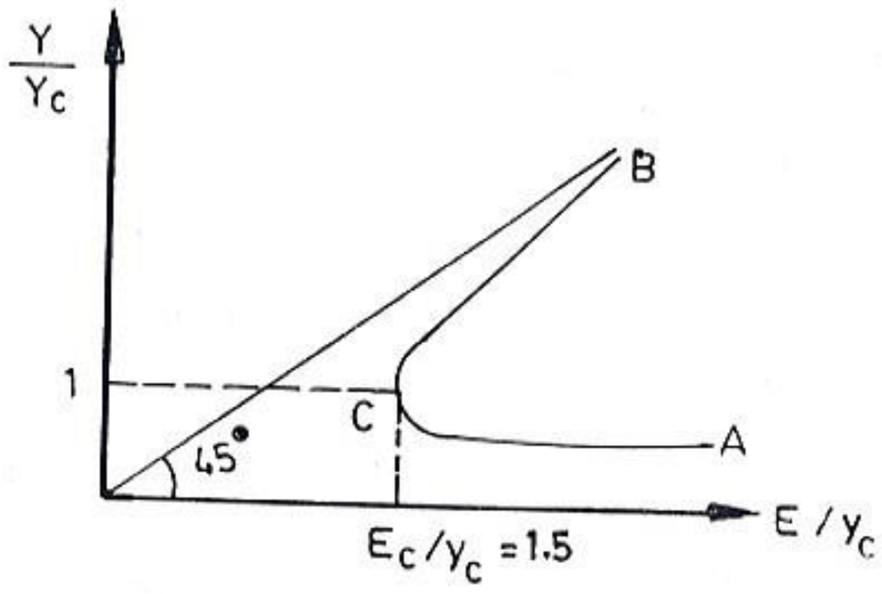

Fig. 2 Dimensionless specific energy curve

Specific force

Specific force is defined as the force at any channel section which is equal to the sum of the hydrostatic force and momentum of the flow passing the section per unit time. For a rectangular channel, the specific force is given by

$F = \frac{1}{2} \rho g b y^3 + \rho Q^2 / by$ …………………………………..6

Specific Force Curve

For a given discharge and section, the specific force F is a function of the depth of flow y only. Plotting the depth of flow y vs the specific force F produces the specific force curve (Fig. 3). This curve has two limbs CA and CB. At y tends to 0 , F tends to infinity. So the limb CA approaches the horizontal axis asymptotically towards the right. Now, at y tends to infinity, F tends to infinity, but at this condition F becomes proportional to y^2 . So the limb CB rises upward and extend infinitely towards the right.

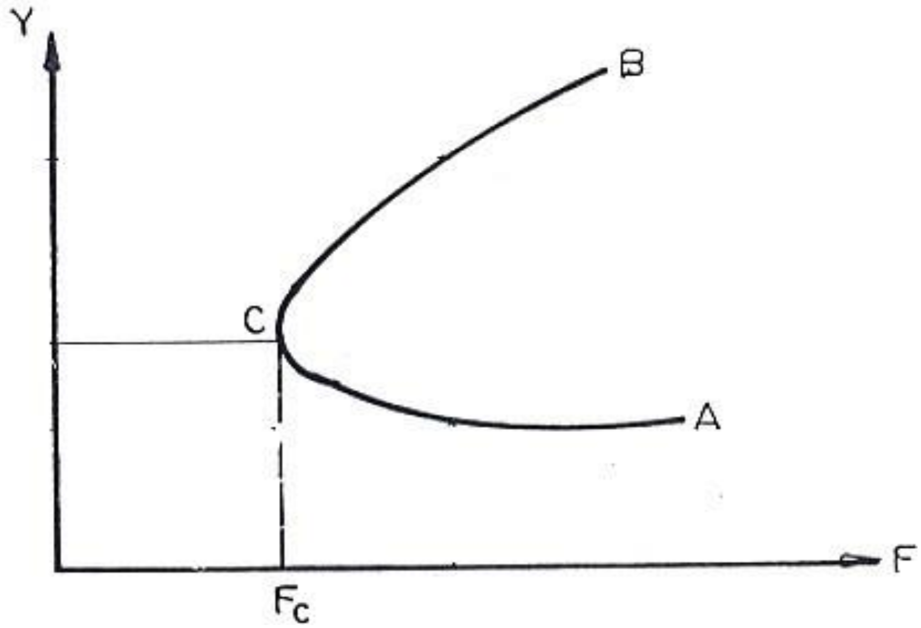

Fig. 3 Specific Force Curve

The specific force curve shows that, for a given specific force, there are two possible depths, y1 and y2. These two depths constitute the initial and sequent depths of a hydraulic jump.

Differentiating Eq. (6) with respect to y and simplifying, we get

$dF/dy = \rho gA - \rho Q^2/AD$

At point C, the specific force is minimum. Therefore

$dF/dy = 0$ or, $\rho gA = \rho Q^2/AD$ or, $Q^2/gDA^2 = 1$ so that $Fr^2 = 1$ or $Fr = 1$

which is the same criteria developed for the minimum value of specific energy. Therefore, for a given discharge, minimum specific force occurs at minimum specific energy or at the critical state of flow.

Generalized Specific Force Curve

If the discharge changes, the specific force also changes accordingly, i.e. the specific force curve moves to right if the discharge is increased and vice versa. In order to develop a generalized specific force curve, i.e. to use one specific force curve for different discharges, the curve is to be made dimensionless with respect to the critical depth as the critical depth yc is constant for a given discharge. So dividing both sides of Eq. (6) by $y_c^2 \rho g b$ and after simplification, we obtain

$$F/y_c^2 \rho g b = y_c/y + 1/2\,(y/y_c)^2 \qquad \text{..7}$$

Equation (7) is the generalized specific force equation and each term of this equation is dimensionless. The plot of this equation is shown in Fig. 4.

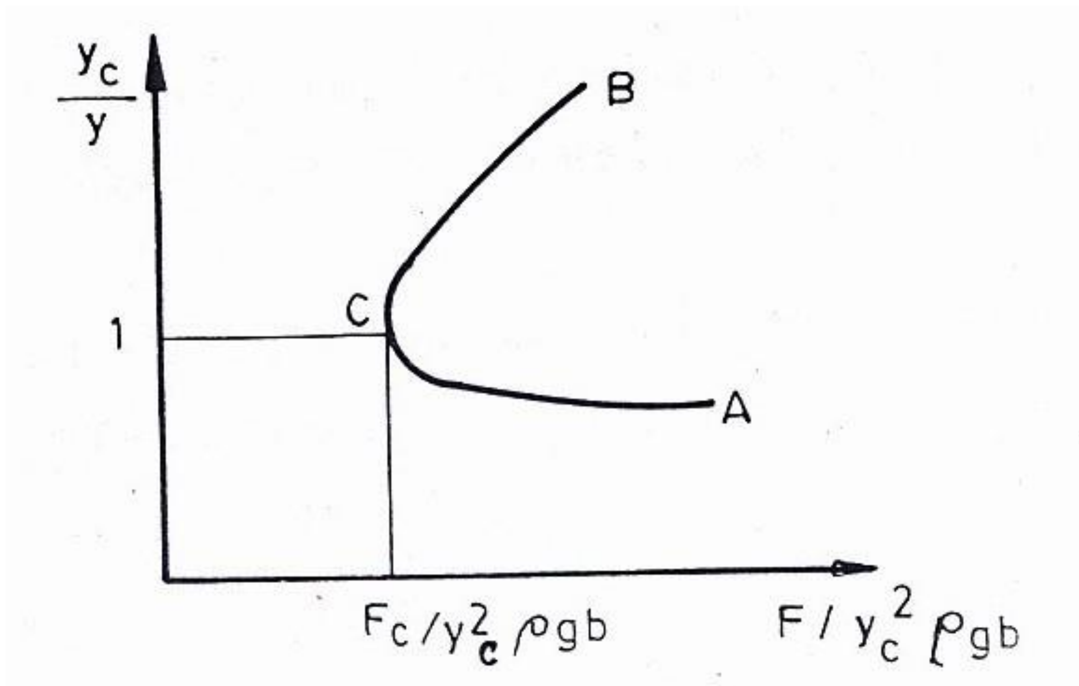

Fig. 4 Dimensionless specific force curve

3. Objectives of the Experiment

- To observe the flow profile in the experimental setup which depicts the variation of depth with change in energy.
- To plot the generalized specific energy and specific force curves from observed data.

4. Experimental Setup

To plot the generalized specific energy and specific force curves, we have to observe the response of subcritical (slow) and supercritical (fast) flows to changes in the energy and force of a stream. For this, the setup as in Fig. 5 can be used

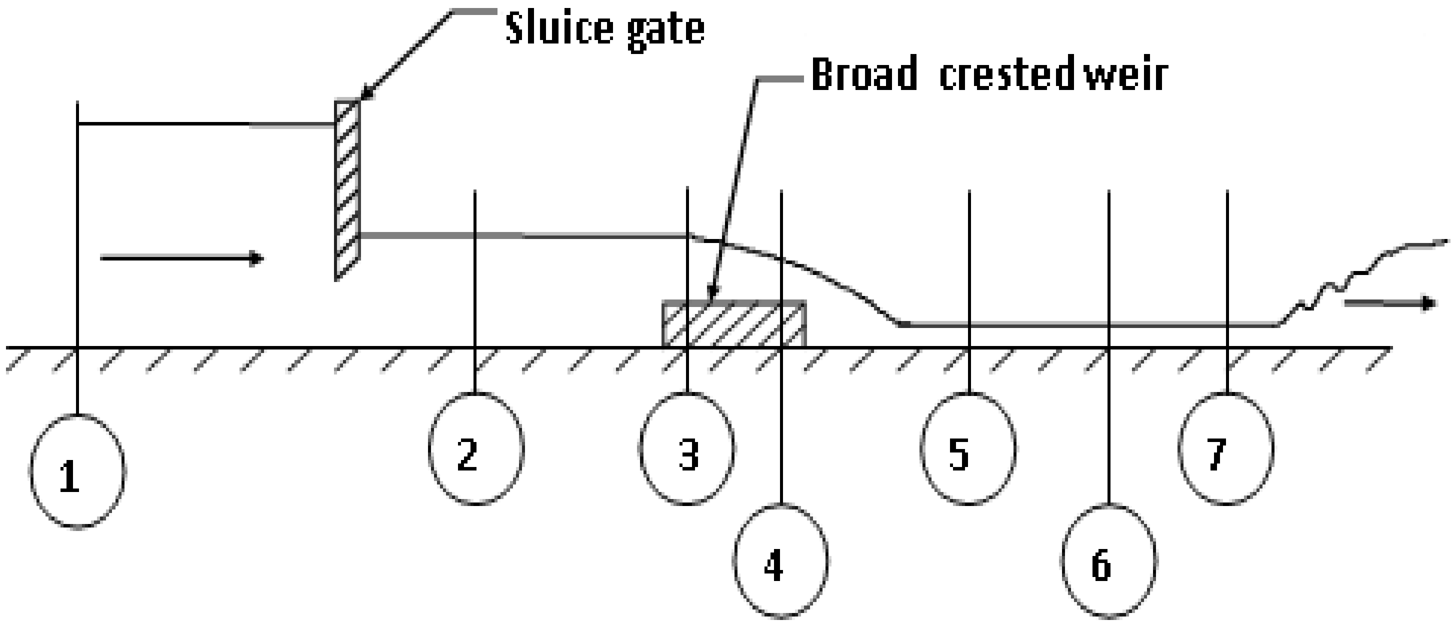

Fig. 5 Setup for development of generalized specific energy and specific force curves

5. Procedure

- Determine depth of flow at three points as shown in Fig. 6 in each of the sections 1 to 7. Find the average depth for each section.
- Determine the actual discharge from the water meter and compute yc.
- Compute E/y_c and $F/y_c^2\rho gb$ for each of the sections using Eqs.(5) and (7), respectively.
- Plot y/y_c vs E/y_c and y/y_c vs $F/y_c^2\rho gb$ on plain graph papers to get the generalized specific energy and specific force curves.

6. Experimental Data Sheet

Q = cm^3/s b =7.7 cm $y_c = (Q^2/gb^2)^{1/3} =$ cm

Section	y_1 (cm)	y_2 (m)	y_3 (cm)	*y =(y1 + y2 + y3)/ 3* (cm)	y/y_c	E/y_c	$F/y_c^2\rho gb$
1	15	15	15	15	7.6	7.62	29.12
2	12.9	12.9	12.9	12.9	6.55	7.56	21.59
3	2.6	2.3	2.2	2.367	1.2	1.55	1.55
4	1.9	1.8	1.4	1.767	0.89	1.52	1.52
5	1.2	1.2	1.2	1.2	0.61	1.96	1.83
6	1.1	1.1	1.1	1.1	5.56	2.17	1.95
7	1.2	1.2	1.2	1.2	0.61	1.96	1.83

7. Sample Calculation

(Graph must be added between sample calculation and results)

8. Results

9. Discussion on Results

10. Assignment

i. How can you apply the dimensionless specific energy and specific force curves for computing specific energy and specific force for different discharges?

ii. Can you use the dimensionless specific energy curve to find the specific force and vice versa? Explain.

iii. Differentiate total energy with specific energy.

iv. What are the significance of alternative depth in specific energy curve?