Discussion on Transition Losses in Open Channels

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The authors are to be congratulated for presenting the results of their experiments on transition losses in open channels.

An open channel transition may be defined as a change either in the direction, slope, or cross-section of the channel, which produces a change in flow conditions (non-uniform flow). Transition sections are needed where conduit or channel cross-sections, and consequently velocities, are appreciably changed. The purpose of a transition structure is to minimize flow disturbances, thereby minimizing the energy losses in the transition. The general approximate submerged flow equation for flow measuring flumes is

$$Q = \frac{C_1 (y_u - y_d)^{n_1}}{[-(\log S + C_2)^{n_2}]} \tag{4}$$

where y_u is a flow depth upstream from the constriction, y_d a flow depth downstream from the constriction, S the submergence $= (y_d:y_u)$, C_1 a submerged flow coefficient, n_1 the free flow exponent, C_2 assumed as a constant for the approximate submerged flow distribution (Skogerboe, 1967), and n_2 a submerged flow exponent. In many cases, C_2 can be taken as zero because it is a small number which approaches zero when the submergence approaches unity. A general equation describing energy loss in an open channel constriction can be obtained by substituting E_u for y_u and E_d for y_d, in which E_u and E_d are the specific energies upstream and downstream from the constriction, respectively. By defining the specific energy ratio, $E_d:E_u$, as E_r, and recognizing that the difference in specific energy, $(E_u - E_d)$, is the energy loss (headloss, h_L), the general energy loss equation can be written as

$$Q = \frac{C_1 h_L^{n_1}}{[-(\log E_r + C_2)]^{n_2}} \tag{5}$$

For open channel expansions, equation (5) can be shown as describing the energy loss. If C_2 is assumed to be zero,

$$Q = \frac{C_1 h_L^{n_1}}{(-\log E_r)^{n_2}} \tag{6}$$

Equation (4) to (6) could have been used by the authors instead of the routine dimensional analysis method of solving the problem.
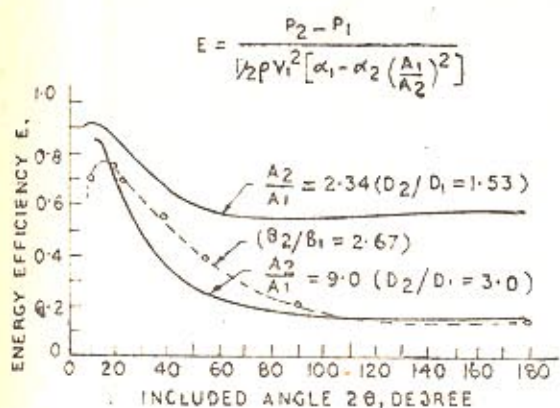
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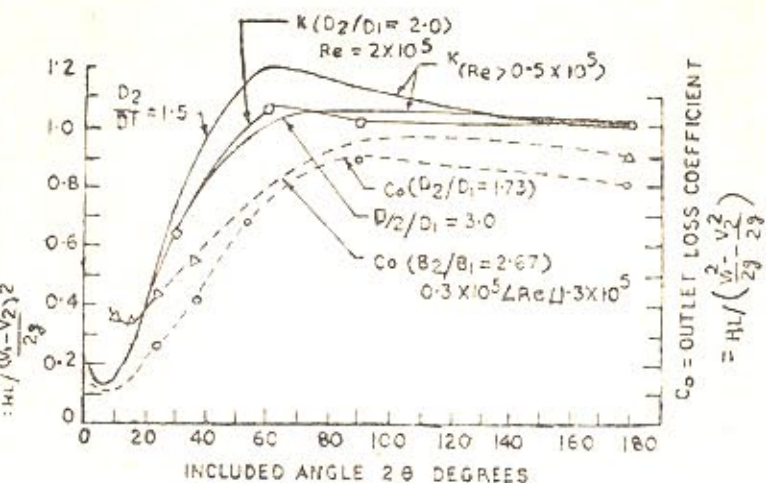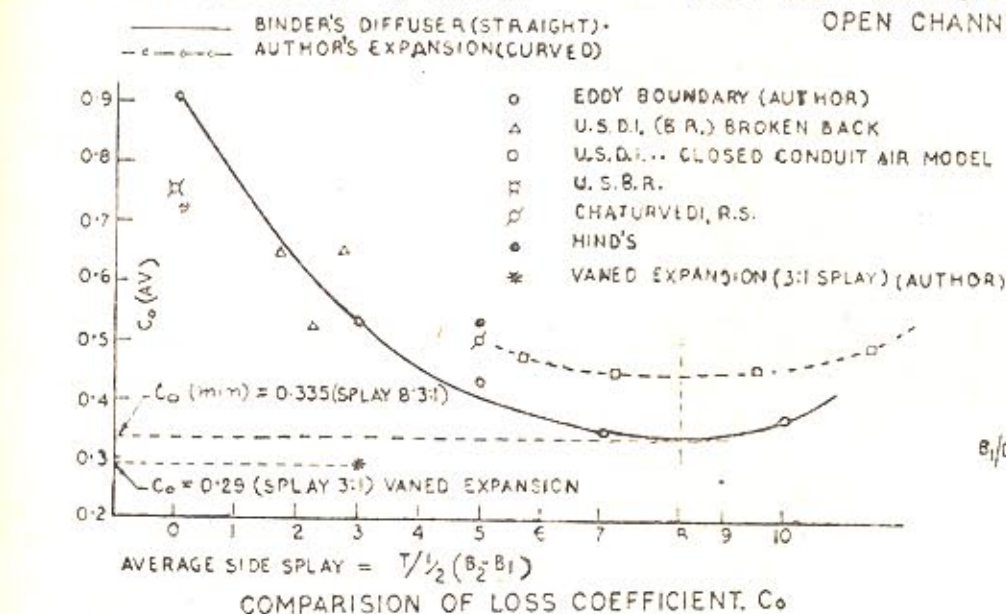
Dr S K Mazumder

The authors have concluded that in subcritical flow through an expansion, headloss is dependent mainly on the discharge, Q, and the expansion ratio, $B_2:B_1$. Angle of expansion, α as well as Froude's number upstream, F_{r1}, as per authors' experimental results do not have much effect on headloss.

These results are, however, completely in contradiction with those obtained by the discusser[3,4] and others[5-7]. Headloss in an expansion with subcritical flow both upstream and downstream is found to vary mainly with the angle of expansion. Fig 17 gives the variation of outlet loss coefficient with angle of expansion as obtained experimentally by the discusser and others. It is found that the loss in head is minimum at a total angle of eppansion of a proximately 10° and maximum at an angle of 60° approximately.

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$$E = \frac{P_2 - P_1}{\frac{1}{2}\rho V_1^2 \left[\alpha_1 - \alpha_2 \left(\frac{A_1}{A_2}\right)^2\right]}$$

$\frac{A_2}{A_1} = 2 \cdot 34\,(D_2 / D_1 = 1 \cdot 53)$

$(B_2 / B_1 = 2 \cdot 67)$

$\frac{A_2}{A_1} = 9 \cdot 0\,(D_2 / D_1 = 3 \cdot 0)$

ENERGY EFFICIENCIES OF EXPANSION

$K(D_2/D_1 = 2 \cdot 0)$
$Re = 2 \times 10^5$ $K\,(Re > 0 \cdot 5 \times 10^5)$

$\frac{D_2}{D_1} = 1 \cdot 5$

$C_0\,(D_2/D_1 = 1 \cdot 73)$

$D_2/D_1 = 3 \cdot 0$

$C_0\,(B_2/B_1 = 2 \cdot 67)$
$0 \cdot 3 \times 10^5 \angle Re \angle 3 \times 10^5$

LOSS COEFFICIENTS FOR CONICAL DIFFUSERS & OPEN CHANNEL EXPANSIONS

——— BINDER'S DIFFUSER (STRAIGHT)·
– – – AUTHOR'S EXPANSION (CURVED)

o   EDDY BOUNDARY (AUTHOR)
△   U.S.D.I. (B.R.) BROKEN BACK
◇   U.S.D.I... CLOSED CONDUIT AIR MODEL
¤   U.S.B.R.
◢   CHATURVEDI, R.S.
●   HIND'S
∗   VANED EXPANSION (3:1 SPLAY) (AUTHOR)

GIBSON
M.C. CHATURVEDI
FORMICA
AUTHORS EXPANSION (CURVED)

STRAIGHT DIFFUSER

$C_0\,(min) = 0 \cdot 335\,(SPLAY\ 8 \cdot 3 : 1)$

$C_0 = 0 \cdot 29\,(SPLAY\ 3 : 1)$ VANED EXPANSION

AVERAGE SIDE SPLAY $= T / \frac{1}{2}\,(B_2 - B_1)$
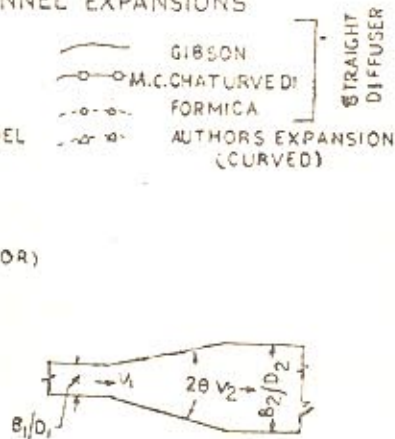
COMPARISION OF LOSS COEFFICIENT, C_0

Fig 17

For angles less than 10°, the friction loss is heavy and there is no form loss, since flow does not separate. For angles lying between 10° and 60°, the headloss is due to both friction and form losses. The rate of increase of form loss due to separation of flow far outweighs the frictional loss which is reduced gradually due to shorter lengths. Net result is sharp increase in headloss after 10°. After 60°, the effect of boundary, so far as headloss is concerned, is practically insignificant, since the flow separates completely from both the boundaries and the headloss is composed mainly of the form loss. It is because of this we notice that there is slight drop in headloss just after 60° (because friction is insignificant) and maintains more or less a constant value up to 180°, i e, the case of abrupt expansion.

Reasons due to which the authors have got no variation in headloss with expansion angle and variation mainly with discharge and expansion ratio (although expansion ratio influences headloss to some extent up to certain limiting value of ratio, discharge should not have appreciable effect on the coefficient of loss) is not known. Discusser, however, feels that the mode of measurement may be one of the factors. Authors have not indicated where the upstream and especially downstream measurements were taken to calculate the values of H_1 and H_2. Values of upstream and downstream depths are not given, nor could these be calculated from the given values of H_1 and H_2 since the width of flume indicated as 0.67 m in the tables do not tally with figures showing 0.33 m flume width.

Tables 1-4 show that the value of downstream Froude's number (F_{r2}) is greater than the upstream Froude's number (F_{r1}) for most of the discharges. This is not possible if the flow is subcritical throughout the reach of expansion. F_{r2} is seen to be greater than unity for the last discharge tested in each series (Tables 1-4). Obviously, the flow was supercritical downstream in these cases. Discusser thinks that the flow downstream was supercritical for some reach and then changed to subcritical stage through feeble jump. Probably the depth has been measured just downstream and within the supercritical region. The values of F_{r2} did not exceed unity in other cases, since F_{r2} was, perhaps, calculated on the basis of mean velocity, rather than the actual velocity of flow at the point of measurement. In an expansion, the downstream velocity distribution is highly non-uniform ; as such local velocity (at the point of measurement) may far exceed the mean velocity of flow. The authors may check up these points by actual measurement of velocity at the point of measurements of depths.

Characteristics of headloss due to an expansion in purely subcritical flow has been shown in Fig 18. Total loss in head (H_L) consists of two parts, H_{L1} inside the expansive zone and H_{L2} in the tail reach X. Since very

little recovery of head takes place in the tail reach, the mean velocity of flow V_2 downstream remains practically the same after the exit end of expansion. Only way, the flow can sustain more kinetic energy is through non-uniformity in velocity distribution. This is exactly what happens in a subcritical trainsition. Immediately after the expansion, the flow is highly turbulent due to separation (for angles greater than 10°) and the velocity distribution is highly non-uniform and that α_2 value is far greater than unity. The excess kinetic energy $(\alpha_2 - \alpha_3)\dfrac{V^2}{2g}$ in production of turbulence gets gradually dissipated in the process of convection, diffusion and dissipation of turbulence in the tail reach, X. After this reach X, the flow is again normal and α_3 value is slightly greater than unity as in normal prarallel flow. Due to pressence of excess kinetic energy, measurement of depth within the reach X is extremely difficult since the flow is eddying and there is considerable fluctuations in depth. It is advisable, therefore, to measure the depth after the reach X, where flow is uniform. It may be emphasized that even slight error in the measurement of depth will cause considerable error in headloss, since the recovery of head is very small. Hydraulic efficiency of an expansion may be defined as

$$\eta_p = \frac{\Delta y}{\Delta y_i} = \frac{\Delta y}{\left(\dfrac{\alpha_1 V_1^2}{2g} - \dfrac{\alpha_3 V_2^2}{2g}\right)} = \frac{\Delta y}{\Delta h_v}$$

where Δy is the actual recovery of head and Δy_i the ideal recovery of head $= \left(\dfrac{\alpha_1 V_1^2}{2g} - \dfrac{\alpha_3 V_2^2}{2g}\right) = \Delta h_v$.

$$\text{Headloss} = H_L = (H_{L1} + H_{L2}) = \left(y_1 + \frac{\alpha_1 V_1^2}{2g}\right)$$
$$- \left(y_2 + \frac{\alpha_3 V_2^2}{2g}\right)$$
$$= \left(\frac{\alpha_1 V_1^2}{2g} - \frac{\alpha_3 V_2^2}{2g}\right) - (y_2 - y_1)$$

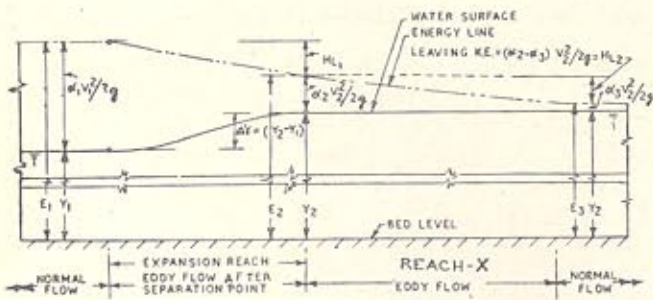$$\text{Headloss} = \Delta h_v - \Delta y \qquad (7)$$

Fig 18 Plain expansion

Defining headloss as $H_L = C_o \Delta h_v$, we have from equation (7),

$$C_o \Delta h_v = \Delta h_v - \Delta y$$

$$C_o = \text{Outlet loss coefficient} = 1 - \frac{\Delta y}{\Delta h_v} = 1 - \eta_p$$

When η_p is expressed in percentage,

$$C_o = \left(1 - \frac{\eta_p}{100}\right)$$

Thus, the headloss being directly related to the recovery of head, Δy, it is of utmost importance that the

loss should be calculated on the basis of actual recovery of head, Δy, measured from a standard datum. The authors may kindly state whether in the measurement of headloss the depths measured upstream and downstream were corrected with respect to some standard datum, eg, still water surface, for example. Otherwise, there is every likelihood of getting wrong results. Since the value of Δy is very small, these measurements should be precisely taken by employing micrometer gauges in stilling wells.

References

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