29.5 Length of the Jump

The length of the jump is an important factor in the design of stilling basins. The beginning of the jump or the toe of the jump can easily be fixed as the mean position of the oscillation at the abrupt rise of the water surface. But there has not been any general accord as to the location of the end of the jump and has become a controversial issue . Riegel Beebe (1917), Ludin (1927), Woycicki (1931), Knapp (1932), Safranez (1933 -39), Aravin (1935), Kinney (1935), Iranchenko, Chertoussou, Page (1935), Bakhmeteff and Matzke (1936), Douma (1934), Posey (1941), Moore (1943) , Wu (1949), and Bradley - Peterka (1955- 57) are some of the investigators , who have proposed definitions for the length of jump. In the following paragraphs the relative merits and demerits of some of the definitions are discussed.

Bakhmetoff and Metzke who were the first to investigate systematically the longitudinal elements of the jump, took the end of the jump as the section of maximum surface elevation before the drop off caused by the channel conditions downstream. In fact, because of the flat nature of the water surface , they could only mark out a region in which the end of the jump could be arbitarily fixed. The jump lengths as given by Bakhmeteff and Matzke are somewhat shorter than the jump lengths produced in wider channels probably because they are affected by the friction of the narrow width of the flume.

Stevens while discussing the paper by Bakhmeteff and Matzke propossed that the length of the jump is a result of two motions : first the translatory motion of the water prism downward and secondly the vertical motion due to the rate of conversion of kinetic to potential energy .

Another definition which seems to have found favour with earlier investigators is that the end of the jump may be taken as the end of the surface roller. But it has been confirmed, firstly by the experimental results reported by Mavis and Luksch (1936) and later by Rouse et al. that the lengh of the jump is always greater than the length of the roller.

Behera and Qureshy, and Qureshy (1947) defined the length of the jump as the distance between the well defined toe and the section at which a cylinder placed in the flow on the floor of the channel will just topple. At first the cylinder should be placed far downstream and moved back upstream until it is toppled by the flow. The shape and size and weight of the cylinder influences the fixing of the length in addition to the forces exerted on the cylinder being affected by the boundary layer near the channel. This definition is from personal error but of little use for designing purposes.

Bradley and peterka (1957) in their investigations on the stilling basins, have defined the end of the jump as the section at which the high velocity jet begins to leave the floor or immediately downstream of the roller, whichever is farther away from the toe of the jump. Instead of defining the end of the jump as the section at which the high velocity jet begins to leave the floor (which does not eliminate the personal error completely) it would have been better if the bed velocity at the end in the downstream channel had been chosen as a certain percentage of the appeoach velocity as suggested by Rajaratnam (1961).

Elevatorski's (1955) definition for the end of the jump is also not much different from the previous roller end definition. Rama Muthy (1960) defined the length of the jump as the distance from the toe of the jump to the section where the flow depth reached a value of 98% of the tailwater level. This definition is free from personal error and agrees with the findings of earlier investigators. However, it is not theoretically sound as the jump is not an asymptotic phenomenon. Nevertheless, it is very useful because of its simplicity. However, this again suffers from the problem of finding the sequent depths accurately.

Rajaratnam in 1961 suggested two criteria for the length of the jump. The first criterion is based on the fact that the mean energy is first transformed into turbulence which later decays through viscous shear. Based on the results of Rouse et al. it can be concluded that the turbulent velocity components become uniform through the depth and decay in the longitudinal direction. The end of the jump may be taken as the section at which the fluctuating velocities are fairly uniform and the level of turbulence is equal to a suitable value determined by the investigation. This definition will help hydraulicians to rationalise the formula but unfortunately there has not been much advancement in measuring turbulence in water and that too in hydraulic jumps which is a two phase phenomenon.

The second criterion is based on the location of the point at which the flow velocity is a certain percentage of the bed velocity. This approach seems to be feasible from the mean velocity data of Moore and Rouse et al. As remarked by Jaeger (1955), the length of the jump is a function not only of the sequent depth but of the energy dissipated in the jump as well. Chandrasekhara Swamy in 1959 gave an analytical equation for two dimensional flow assuming (i) that the flow in the initial section is uniform and free from turbulence (ii) that the mean turbulent stressses are neglected over the free surface and, (iii) that the pressure distribution is hydrostatic. His equation is implicit in nature.

Alternately, the length could be defined as the section at which the bed shear causing the movement of the bed material and is less than the critical tractive force for the particular bed material with a predetermined factor of safety. Based on the mean air concentration distribution along the jump, Rajaratnam suggested that the end section can be chosen at that section where the mean air concentrarion is 2%. As his method of computing the mean air concentration was different from that of the definition given by Straub and Anderson (1958).

Sadasivan in 1977, based on the measurements of random pressure fluctuations, suggested that the length of the jump can be defined as the distance at which the pressure fluctuation subsidises and the free surface becomes constant. However , this cannot be utilised for design purposes and is arbitrary. This length depends on the turbulence levels in the approaching flow and in the roller zone.

Sarma and Newnham by assuming the end of the jump just downstream of the roller and selecting a length short enough to neglect the shear force presented an empirical equation

$$\frac{L_{rj}}{y_1} = 8.75(F_1 - 1) \qquad (29.4)$$

Which is almost comparable to Eq. 29.5 of Tschertoussow except for the exponent.

$$\frac{L_{rj}}{y_1} = 10.3\ (F_1 - 1)^{0.81} \qquad (29.5)$$

However, Equations 29.4 and 29.5 represent only the length of the surface roller. There have been several other investigations such as those of Safranez, Einwachter , Rouse et al. and Rajaratnam . Figures 1.4 and 1.5 show the nondimensional plots of length of roller and length of jump with initial Froude number respectively.Rajaratnam found that the length of the roller is generally less than the length of the jump and approaches the length of jump as the Froude number increases. It was found that the ratio L_{rj} / L_j increases from about 0.4 at F_1 =3.0 to about 0 .70 at F_1 = 9.0.

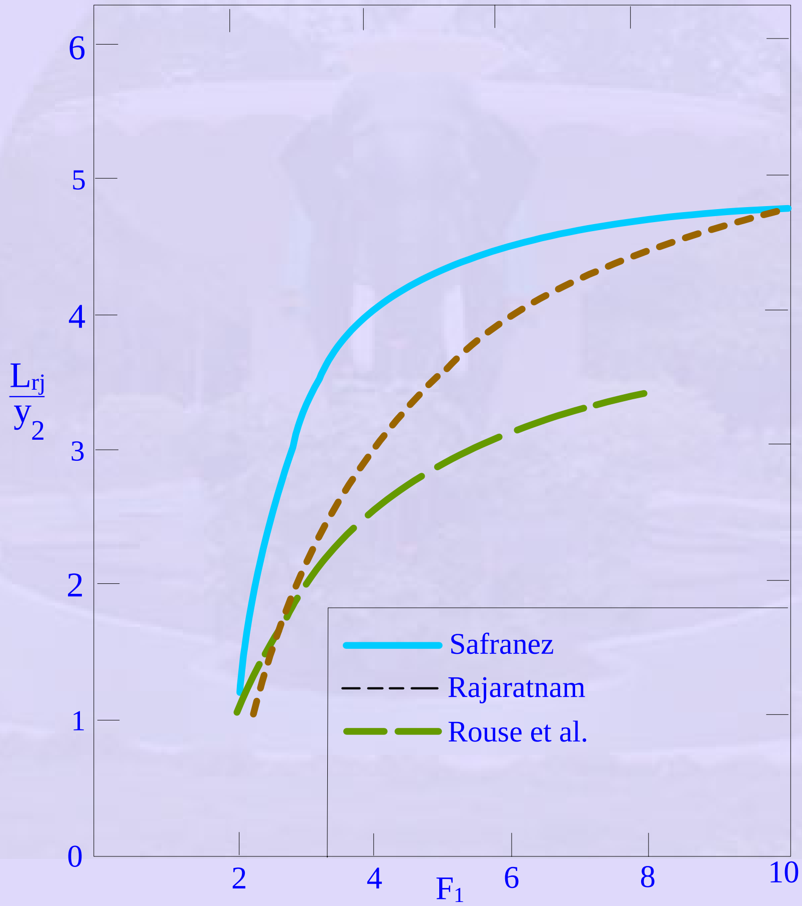

Fig. 29.2 NORMALISED ROLLER LENGTH OF THE JUMP AS A FUNCTION OF INITIAL FROUDE NUMBER

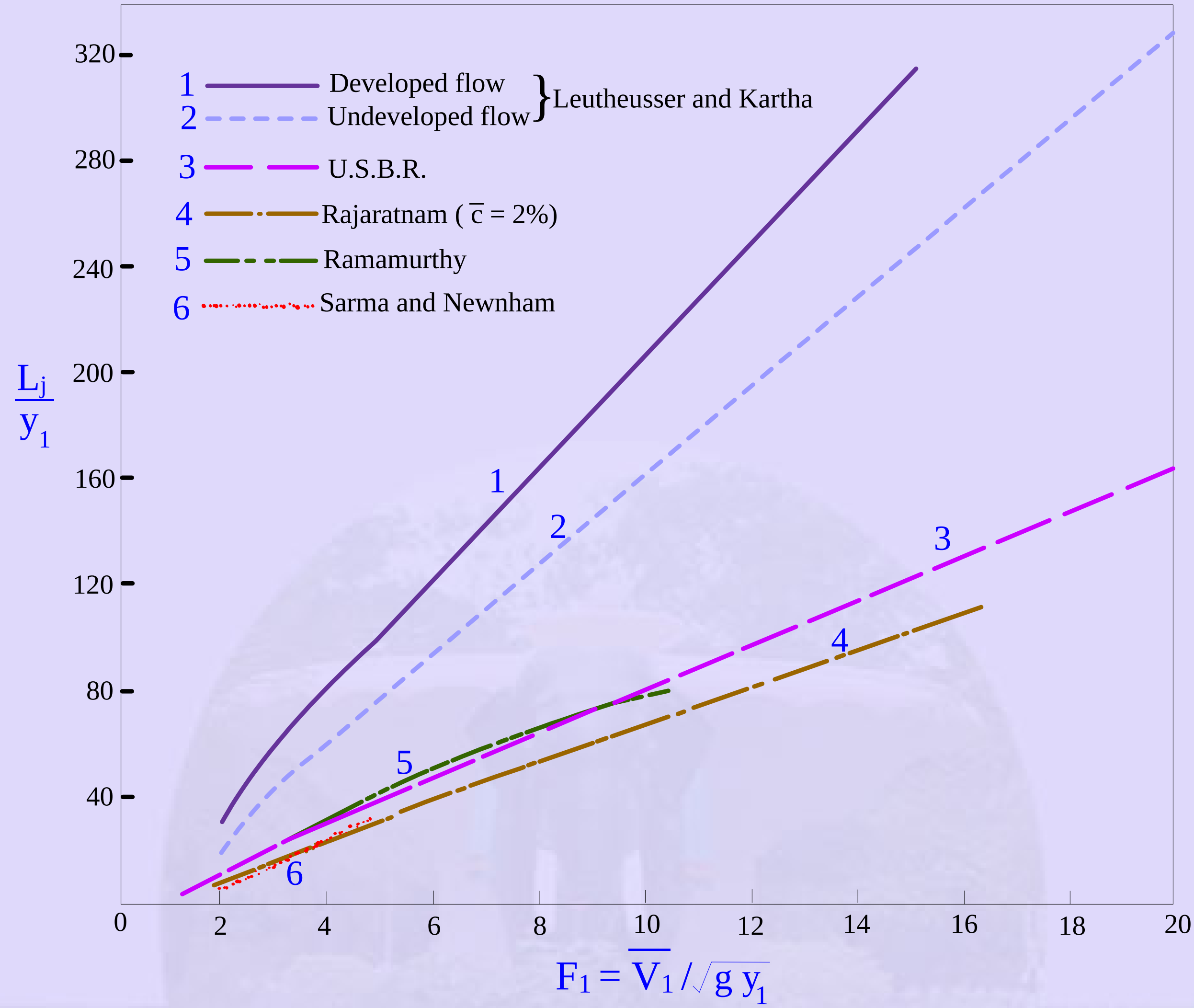

Fig. 29.3 - VARIATION OF NORMALISED LENGTH OF THE JUMP WITH INITIAL FROUDE NUMBER

TABLE 29.1 - Emprical relationships for Length of the Normal Hydraulic jump

Researcher	Emprical relationship
Ludin	$L_j = y_2\left(4.5 - \frac{V_1}{V_c}\right)$
Safranez	$L_j \approx 5.2 y_2$
Bakhmeteff, Matzke	$L_j = 5(y_2 - y_1)$
Knapp	$L_j = \left(62.5\frac{y_1}{E_1} + 11.3\right)\left[\frac{(\overline{V}_1 - \overline{V}_2)^2}{2g} - (E_1 - E_2)\right]$ $E = y + \frac{\overline{V}^2}{2g}$
Smetana	$L_j \simeq 6(y_2 - y_1)$
Kinney	$L_j = 6.02\,(y_2 - y_1)$
Douma	$L_j = 3y_2$
Posey	$L_j \simeq 4.5 - 7(y_2 - y_1)$
Wu	$L_j = 10\,(y_2 - y_1)F_1^{-0.16}$
Woycicki	$L_j = (y_2 - y_1)\left(8 - 0.05\frac{y_2}{y_1}\right)$
Ivanchenko	$L_j = 10.6\,(F_1^2)^{-0.185}(y_2 - y_1)$
Einwachter	$L_{rj} = \left(15.2 - 0.241\frac{y_2}{y_1}\right)\left[\left(\frac{y_2}{y_1} - 1\right) - \frac{\overline{V}_1^2(y_2/y_1 - 1)}{(y_2/y_1)^2 g}\right]$
Chertoussov	$L_j = 10.3 y_1 (F_1 - 1)^{0.81}$
Page	$L_j = 5.6 y_2$
Riegel, Beeba	$L_j \approx 5(y_2 - y_1)$
Aravin	$L_j \approx 5.4\,(y_2 - y_1)$