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Measurements of Turbulence Intensities and Shear Stress of Jumps

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Abstract: The hot film and the hot fibre were the tools of the measurements of the velosity, turbulence, and shear stress occured in the model of the dump used in the study. The previous one was used to measure the horizantal velocity, and the latter was the tool of the turbulance and shear stress measurements. he present study is focused much on the experimental procedure for measurement of different parameters at variaus sections of the hydraulic dump and different froude numbers.Besides that, the present prediction are compared with some previous investigations in this field. Furthermore, the auther concluded that the suitable and sophisticated equipments are necessary in order to get real, and fast results.

Keywords: Turbulence Intensities, Shear Stress, Turbulence

Introduction

The Study of the turbulent shear flows offers a challenge to the theoretical and experimental researchers in order to develop mathematical models of turbulence. The development of the hot wire and hot-film anemometers have given the researchers a tool for studying the shear stress and turbulence intensities. But, There is a need for all types of information in order to study the mean velocity, turbulence and shear stress in the hydraulic jumps for various flow conditions.

Considerable research has been conducted on a free jump. Rouse *et al.* (1985) Carried out early measurements of turbulence in an air model of free jump using hot wire anemometer. They concluded that mixing processes diffused momentum, energy and turbulence laterally and longtiudinally. Based on the measurements of Rajaratnam (1965), it was found that the highest value of the shear stress and the turbulence production were in the region of the maximum velocity gradient.

Using the hot film anemometer as a tool of measurements resch and leutheusser (1972) studied the turbulence in the jump. They discovered internal of condition hydraulic jump formation. Resch (1), Richardson and Mcquivey (1968) and Rouse *et al.* (1985) have employed hot-film anemometer to investigate various characteristics of the free jump. Beside that, diffusion and pressure distribution were studied in submerged jets as well as in submerged jumps(Albertsom *et al.*, 1950 and Dhaimat, 1989).

To the author Knowledge only Rajaratnam (1965) has carried out measurements to study the mean flow characteristics of the submerged jump. The reverse flow velocity distribution and turbulence intensities have not been investigated by him for various submergence conditions. Extensive measurements have been carried out using hot fiber film to measure the turbulence and shear stress (Richardson and Mcquivey, 1968). In the present investigation, turbulence and shear stress in the hydraulic jump are considered using experimental results through computer program and comparing with previous works in this field.

Apparatus: The investigation was carried out in a glass-side flume with a painted floor. The flume was 100mm wide and 2.6m long. The painted floor provided a smooth boundary. Water was fed to the flume under a sluice gate from a settling tank. A manual tailgated was located downstream of channel to control water depth. The submergence of the jump was achieved by raising the tail water depth. A detailed description of the flume is given in Fig. 1.

Two type of anemomenters were employed conical hot film and inclined hot fiber anemometers. The conical hot-film was used to measure the longitudinal velocity component. The hot fiber was used to measure the turbulence intensities and shear stressed. The diagrams of both films are shown in Fig. 2.

Procedure: The mean voltage and voltage fluctuations were obtained by using hot-film and hot fiber anemometers. The hot film anemometer was operated at an overheat ratio of 1.06. The mean voltage velocity relation was determined by using a pitot tube as the velocity standard, measurement.

The shear stress and turbulence intensities were evaluted from a single rotated fiber-film sensing element inserted into the channel. The basic equation can be expressed for small fluctuation quantities as:

$$e' = \frac{\partial E}{\partial U} u' + \frac{\partial E}{\partial \theta} \theta' \qquad (1)$$

In which e'; u' and θ' are the fluctuation quantities of E, U and θ respectively; Where E= the voltage across the sensor, U=the velocity, and θ =the angle incidence. By using

$$e' = \frac{v'}{U}, a = U\frac{\partial E}{\partial U}, and b = \frac{\partial E}{\partial \theta} \qquad (2)$$

In which V' is transverse velocity fluctuation and a and b are hot fiber sensitivities,

Eq. 1 becomes for two directions of the fiber-film as.

$$e_1' = a_1 \frac{u'}{U} + b_1 \frac{V'}{U} \qquad (a)$$

$$e_2' = a_2 \frac{u'}{U} + b_2 \frac{V'}{U} \qquad (b)$$

(3)

The solution for the nondimensional components to turbulence intensities is expressed as:

$$\frac{u'}{U} = \frac{b_2 e_1' + b_1 e_2'}{a_1 b_2 + a_2 b_1} \qquad (a)$$

$$\frac{V'}{U} = \frac{a_2 e_1' - a_1 e_2'}{a_1 b_2 + b_1 a_2} \qquad (b) \qquad (4)$$

The correlation u v is obtained as:

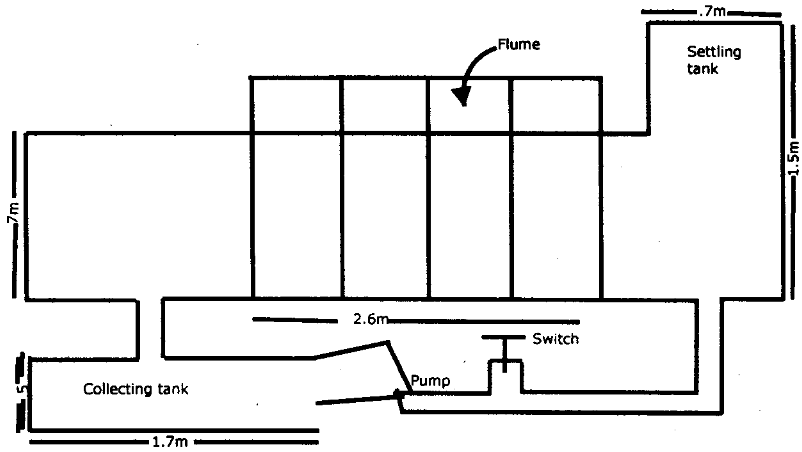

Fig. 1: Side Elevation of Flume

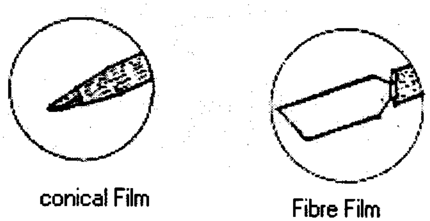

Fig. 2: Diagrams of Film

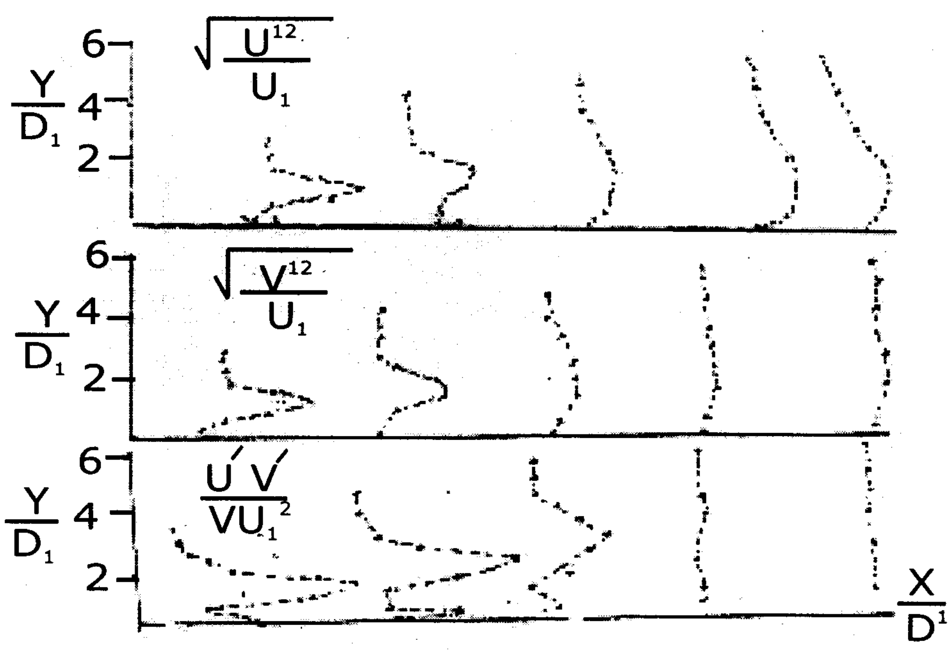

Fig. 3: Distribution of Intensities and Shear Stress

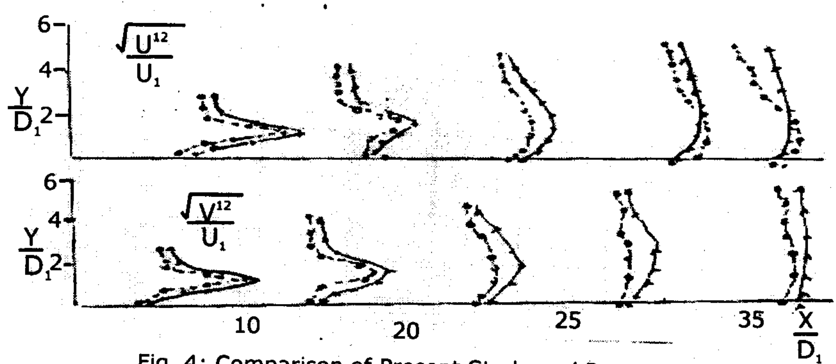

Fig. 4: Comparison of Present Study and Rouse *et al.*, (Fr-6.0)

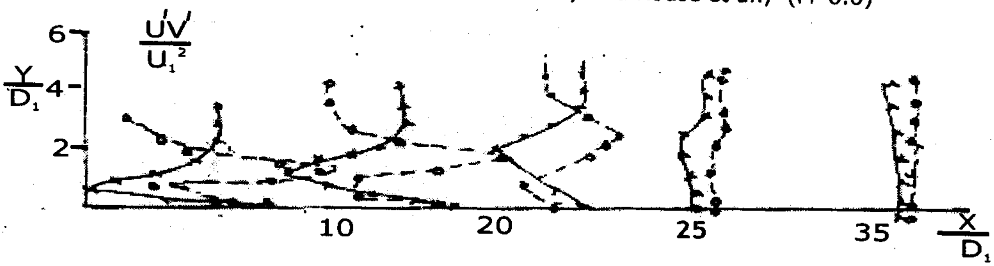

Fig. 5: Comparison of Present Study and Rouse *et al.*, (Fr-6.

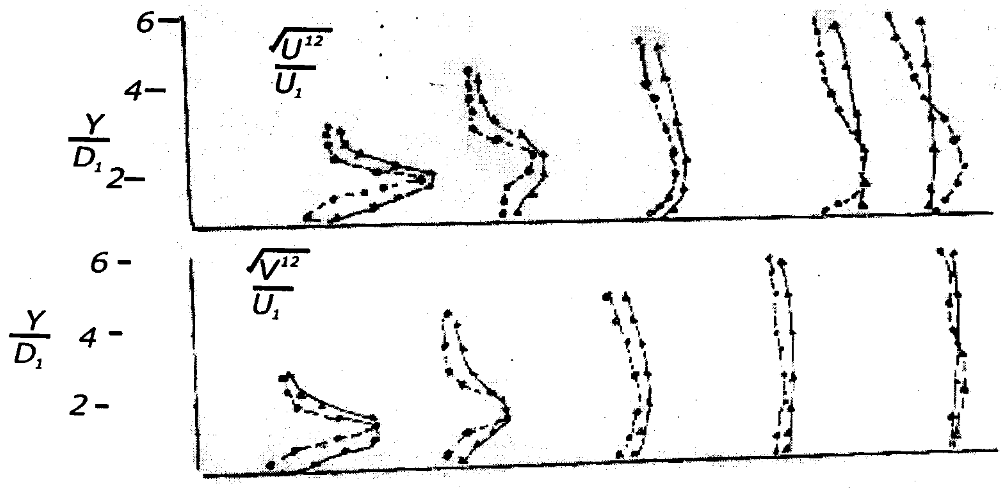

Fig. 6: Present Study and Resch and Leutheusser (Fr=6.0)

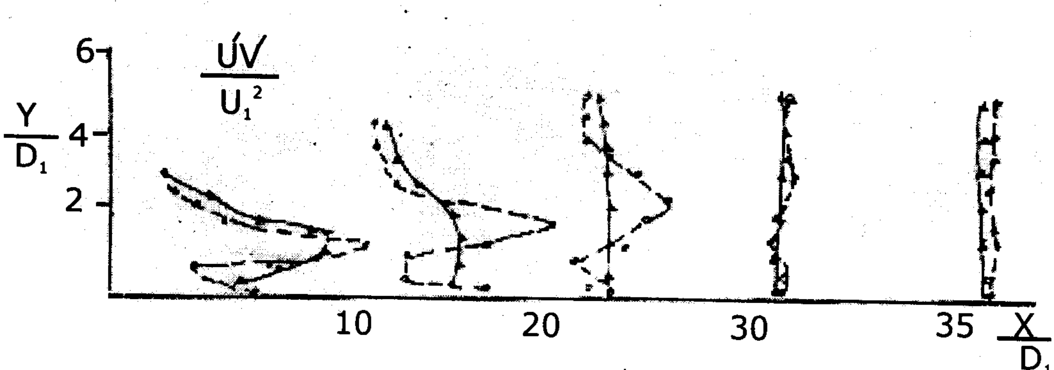

Fig. 7: Present Study and Resch and Leutheusser (Fr=6.0)

$$\frac{u'v'}{U^2} = \frac{b_2 a_2 e_1'^2 + e_1' e_2'(b_1 a_2 - b_2 a_1) - b_1 a_1 e_2'^2}{(a_1 b_2 + b_1 a_2)} \tag{5}$$

The fiber sensitivities a and b are determined by

$$a = U_{eff} \frac{\partial E}{\partial U_{eff}} \tag{6}$$

And

$$b = \frac{a(k^2 - 1)\sin\theta}{2(\cos^2\theta \pm k^2 \sin 2\theta} \tag{7}$$

In which

$$U_{eff} = U(\cos^2\theta + k\sin 2\theta) \tag{8}$$

And K is the overheat ratio
According to Richardson and McQuivey

$$\frac{\partial E}{\partial U} = \frac{B}{4E\sqrt{U}} \tag{9}$$

In which B is a constant of the calibration curve.

Results and Analysis: Applying the previous equations to each pair of digitized values (e, e) and averaging with respect to time, led to obtain the turbulence intensities and shear stress by using cobputer program.

The Procedure required careful control of dirt contaminate and fluid temperature, which change, the hot films sensitivity. During calibration and operation dirt deposit was controlled by using sieve as a filter in the settling tank and the sensor was cleaned with a small brush before each measurement. Fluid temperature was controlled by selecting small overheat ratio (1.06).

At three supercritical depths of 5mm, 10mm and 20mm. The mean velocity, the tubulence intensities and the shear stress were measured. Various cases were studied in which the froude number varied from 2.5-7.0. Measurement were made at various cross sections from beginning of the jump to the tailgate. The results of the measurement are shown graphically. Fig. 3 shows the turbulence intensities in free jump for Froude number 6. Its seen that the magnitude of the horizontal turbulence is more than the vertical one. But, the fluctuations of both intensities are much at the beginning of the jump and become less down stream. This happens due to the formation of the reverse flow (roller area) within the jump, which dissipates a great amount of energy.

It is shown that the direction of the distribution of shear stress follows the same case of the turbulence intensities. But, the magnitude is more intense at the beginning of the jump rather the previous turbulence intensities as a correlation of these intensities.

Also, the present results are plotted on the same diagram with Rouse *et al*. (1985) investigation as shown in Fig. 4. It is seem that the distribution of the turbulence of the both results in look like the same with small devitation, although there is a difference in the tools and fluid. But, The direction of the shear stress distribution of Rouse *et al*. (1985) Results is in opposite direction of the present investigations at the beginning of the jump, because they are following the sign of the Boussinesq-Prandtle approximation as shown in Fig. 5.

Furthermore, the results of Resch and Leutheusser (1972) are compared with the present study. Fig. (6) indicates that the both results o the turbulence intensities are coincided with each other. But as shown in Fig. (7), there is a difference in the shear stress distribution, where the present study dictate more intensity than others along the length of the jump.

Notations:

a, b	=Fiber film sensitive.
B	=Constant in calibration
E	=Voltage
K	=Oversheat ratio
U	=Horizontal Velocity
V	=Vertical Velocity
U1	=Supercritical Velocity
Ueff	=Effective Velocity
e'	=Voltage Flucation
θ	=Angle of the incidence
θ'	=Angle Fluctuation
u',v'	=Fluctuation of horizontal and transverse velocity respectively
u' v'	=Turbulent shear stress.

Conclusion

The analysis of the experimental results shown that the magnitude of the turbulence intensities as well as the shear stress is more at the beginning of the jump. But, It is decreasing down-stream due the formation of reverse velocity and increasing of flow depth. The former dissipates energy and the latter decreases the flow turbulence.

Also, control of dirt contamination and fluid temperature are necessary for film sensitivity during the calibration and operation in order to get real information of velocity, intensities, and shear stress.

Finally, sophisticated equipment's and tools are necessary in order to get real, fast and comprehensive information

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