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EXTENDED ABSTRACT

Investigation of Pressure Fluctuations of Hydraulic Jump on Rough Bed

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Introduction

A hydraulic jump is a sudden transition from a supercritical to subcritical flow with a broad range of turbulence Scales. The fluctuating nature of the flow such as oscillations of jump toe position and production of large eddies are visible in pseudo-periodic manners. Energy dissipation of hydraulic jump occurs with Low-frequency large scale pressure fluctuations which can cause damage and erosion and endanger the security of the structures. In the present study, the effects of discontinuous roughness elements of lozenge shape on the fluctuations of pressure in hydraulic jump have been investigated.

Methodology

The experiments were conducted in a flume with a length of 10.0 m, width of 0.5 m, and depth of 0.60 m at the hydraulic engineering laboratory of the University of Tabriz. The lozenges shape roughness elements with the heights of 1.4 cm ($h/y_1=0.67$) and 2.8 cm ($h/y_1=1.33$) and density of 10.67% were installed on the horizontal bed in such a way that the crest of elements was at the same level as the upstream and downstream bed, therefore, the elements are not directly subjected to the incoming jet. The shape of roughness elements was selected according to the study of Shafai Bajestan and Neisi 2009 and they were distributed in a staggered way on the bed. The distances between the roughness elements in the Transverse and longitudinal directions were obtained according to the dimensions of the roughness elements and the stilling basin. The hydraulic jump was formed on the installed roughness elements in the stilling basin with the length of 210 cm, which was located at a distance of 158 cm from the upstream sluice gate.

In order to measure dynamic pressures, 30 piezometers were installed on the central axis of the flume. The instantaneous pressures of the various piezometers installed on the rough bed were converted into electrical signals by pressure transducers via a 6-channel digital board, calibrated in for the range of ±100 mbar, and after processing of the signals using the DAQ system, the recorded data were displayed by the computer using the 6CH Pressure DAQ software.

Results and Discussion

Because of highly random nature of dynamic pressure fluctuations, the analysis is based predominantly on statistical methods. Three dimensionless pressure coefficients are defined as:

$$C_p^+ = \frac{P_{max} - P_{avg}}{\alpha V_1^2/2g},\; C_p^- = \frac{P_{min} - P_{avg}}{\alpha V_1^2/2g},\; \acute{C}_p = \frac{RMS}{V_1^2/2g} \qquad (1)$$

Where P_{max} = the maximum pressure, P_{min}=the minimum pressure, P_{avg} = the mean pressure, RMS is standard deviation; V = the incident flow velocity; and g = the acceleration of gravity.

Figure 1 shows the dimensionless RMS of fluctuating pressures in hydraulic jump on the rough bed. It can be observed from the figure that the distributions of Cp rapidly increased at the beginning of the jump until a maximum value then its value decreased toward the down stream and got close to each other at the end of the hydraulic jump.

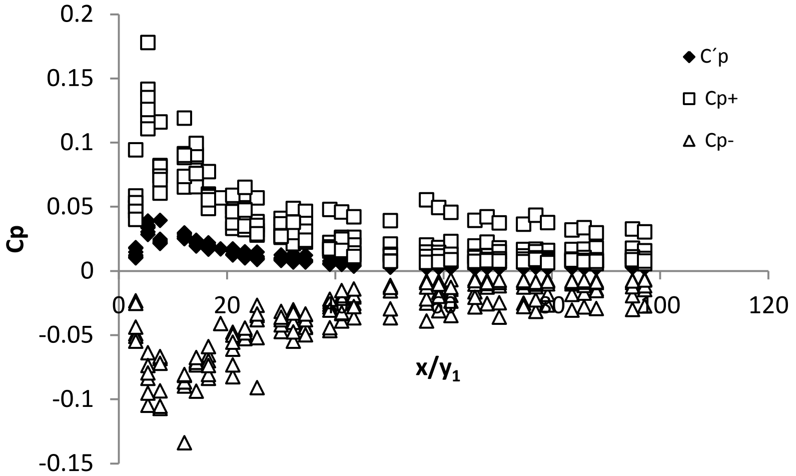
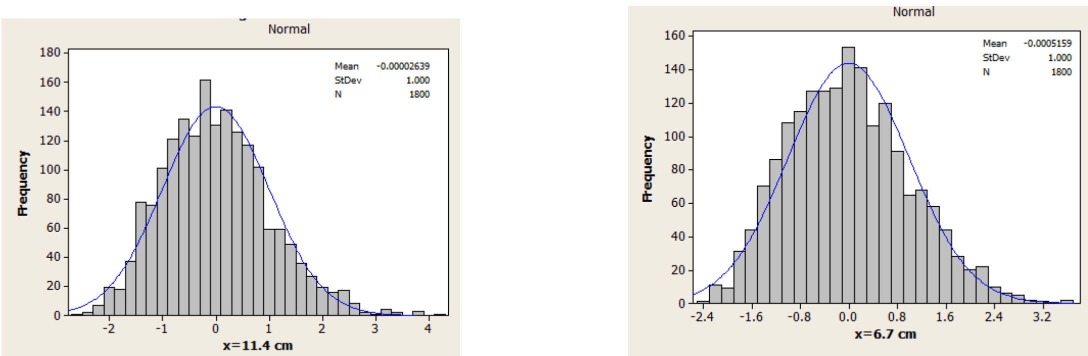


Figure 1– Pressure coefficient in dimensionless longitudinal distances of hydraulic jump on rough bed

The purpose of drawing the probability density function is to obtain the probable pressure with a probability of occurrence. In Fig. 2, the probability density function and the normal distribution are plotted for 5 piezometers at longitudinal intervals of 6.7, 11.4, 16.1, 25.5 and 30.2 cm from the beginning of the jump, in the Froude number of 12.3 with roughness elements of h/y_1 = 1.33. As it can be seen, the distribution of these functions is consistent with normal distribution and there is no significant difference.



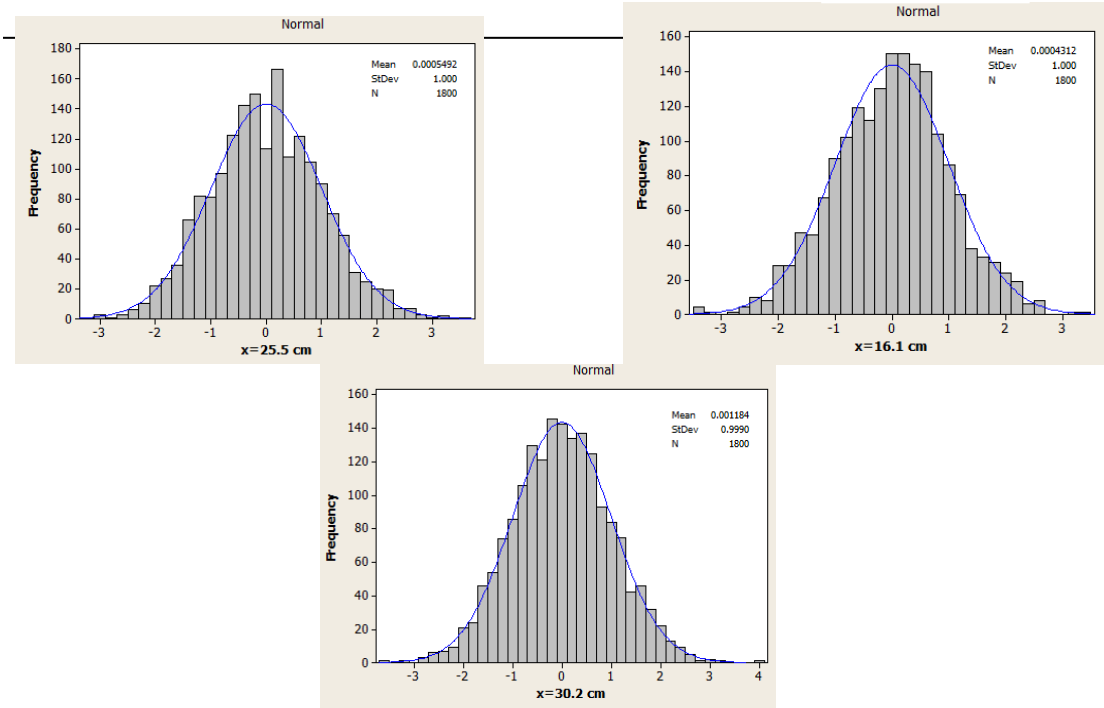


Figure 2– Probability density distributions of pressure fluctuation on rough bed h/y_1=1.33

Conclusion

In the present study, the hydrodynamic characteristics of hydraulic jump on a rough bed with two roughness heights of 1.4 and 2.8 cm were studied. According to the results, by increasing of the Froude number, the pressure fluctuations increases because of the increasing of turbulence intensity in the hydraulic jump. The values of the pressure standard deviation coefficient at the beginning of the hydraulic jump increased to its maximum value, then decreased and at the end of the jump its value is almost constant. In fact, at the beginning of the hydraulic jump near the toe, strong vortices below the jump forms, towards the downstream by increasing of the depth of water and as a result of the energy depletion, the intensity of the flow turbulence decreases. The pressure fluctuations on the rough bed are higher than the classic jump at $x/y_1 < 20$ and towards downstream of the jump decrease about 80% compared with the hydraulic jump on the smooth bed. The variations of the average pressure in the hydraulic jump on the rough bed are almost constant at relative length of $x/(y_2 - y_1) = 7$. In the present study, the peak value of C_p^+ and $|C_p^-|$ were obtained 0.178 and 0.134, respectively.

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