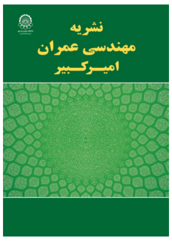

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# Pressure Fluctuations in Hydraulic Jump Investigation of Stilling Basin at Sudden Expansion

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**Abstract:** The hydraulic jump in the stilling basin can be considered macroscopically as a time-averaged steady, abruptly varied flow characterized by a free surface discontinuity and the formation of strong vortex that generates macro turbulent fluctuations. This paper are discussed the characteristics of pressure fluctuations in spatial hydraulic jumps with sudden expansion stilling basin. The effects of the channel expansion ratio and inflow condition on the dimensionless standard deviation of pressure fluctuations (cp') and extreme pressure fluctuations (Cp+, Cp-) in the hydraulic jump were examined. In this study many tests were conducted in a relatively large flume size of 0.8 meter wide and 12 meter length. data were presented for Froude numbers from 2.5 to 9.5 and channel expansions ratio (B1/B2) was 0.33, 0.5, 0.67 and 1. Pressure data were recorded by means of pressure transducers systems. A sampling frequency of 40 Hz was selected. The results show that the dimensionless standard deviation of pressure fluctuations and extreme pressure fluctuations of the hydraulic jump are dependent on the inflow Froude number and position from the toe of the jump. Fluctuating pressure at the position of about (10-30)Y1, can reach the maximal value. And indicates that the sudden expansion at the hydraulic jump decreases pressure fluctuations. The dimensionless standard deviation of pressure fluctuations (Cp') decreases on the order 43%, 38% and 19% for expansions ratio 0.33 , 0.5 and 0.7, respectively compared with classic jump.

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## 1- Introduction

Hydraulic jump is a rapidly varied transition from supercritical to sub-critical flow through which energy is dissipated due to generation of large-scale turbulence. The process of energy dissipation in hydraulic jump is associated with hydrodynamic pressures acting on the floor and sidewalls of stilling basins. Damages due to pressure fluctuations under hydraulic jump have occurred in several stilling basins around the world. Lifting up the whole floor slabs, fatigues of materials and cavitations are the main damages cause by pressure fluctuations. Major damages due to pressure fluctuations have been reported in several stilling basins such as: Karnafuli dam in Bangladesh and Malpaso in Mexico (Bowers et al 1964; Bowers and Toso 1988). More recent studies on the subject, pay more attention to the fluctuating pressures under different types of hydraulic jumps. But few researchers studied the effect of side eddies on the fluctuating pressure beneath hydraulic jump. When a hydraulic jump takes place in a channel expansion, it is influenced by the formation of side eddies. In a sudden expansion section may be formed three types of jump:

- 1-Repelled hydraulic jump
- 2-Spatial hydraulic jump
- 3-Transitional hydraulic jump

When the toe of the jump locates at the expansion section, a spatial hydraulic jump occurs and it has asymmetric flow (Figure 1). In this article, the fluctuating pressures in spatial hydraulic jump (S-jump) were measured. The results were also compared with those of equivalent classical jumps.

## 2- Methodology

Experimental investigations were carried out at the Engineering Hydraulics Laboratory of Shahid Chamran University in a glass walled rectangular flume.

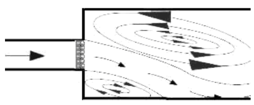

**Figure 1: Spatial hydraulic jump**

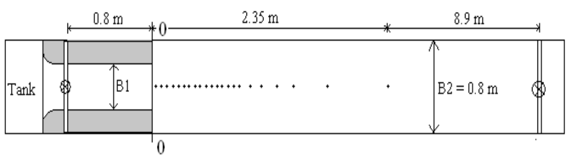


**Figure 2: Schematic of the experimental setup**

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A sluice gate was placed at the inlet of flume to control the depth and velocity of incoming flow, while the location of jump was controlled by a tail gate placed at the end of the flume. The experiments were respectively conducted on the models with expansion ratio (B1/B2) 1.0, 0.67, 0.5 and 0.33. Pressures fluctuations were measured using pressure transducers. A sampling rate of 40 Hz was used in this study.

## 3- 3-Numerical and Dimensional Analysis

Because of highly random nature of fluctuations, the analysis is based predominantly on statistical methods. There are three types of dimensionless pressure coefficients:

$$C'_p = \sqrt{\overline{(p')^2}} / \frac{V_1^2}{2g} \quad (1)$$

$$C_p^+ = \Delta p^+ / \frac{V_1^2}{2g} \quad (2)$$

$$C_p^- = \Delta p^- / \frac{V_1^2}{2g} \quad (3)$$

Where $p'$ is fluctuating component (m), $V_1$ is the inflow velocity (m/s), g is the gravitational acceleration (m/s$^2$), $\Delta p^+$ and $\Delta p^-$ are the maximum positive and negative pressure deviation from the mean pressure. For Dimensional analysis using the Buckingham theorem:

$$C'_p = \frac{\sqrt{\overline{(p')^2}}}{V_1^2 / 2g} = f\left(\frac{1}{F_1^2}, \frac{Y_2}{Y_1}, \frac{X}{Y_1}, \frac{B_1}{B_2}\right) \quad (4)$$

## 4- Discussions

Figure 3 shows the dimensionless RMS of fluctuating pressures in spatial hydraulic jump. It can be observed from the figure that the distributions of Cp' are a function of the incident Froude number and in different Froude numbers follow the similar trend. It rapidly increased until reached a maximum value then its value decreases.

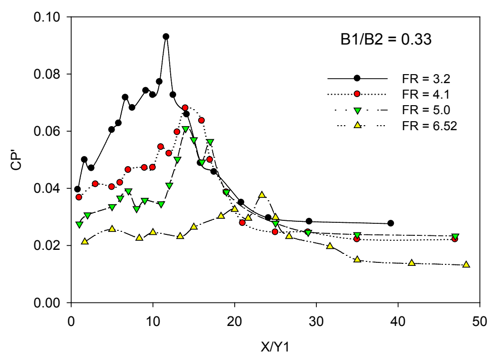


**Figure 3: Dimensionless rms of pressure fluctuations**

Figure 4 shows maximum value of Cp' for different Froude numbers in hydraulic jump with expansions ratio of 0.33, 0.5, 0.67 and 1. The results indicate that the value of $Cp'_{max}$ decreases with increasing Froude number.

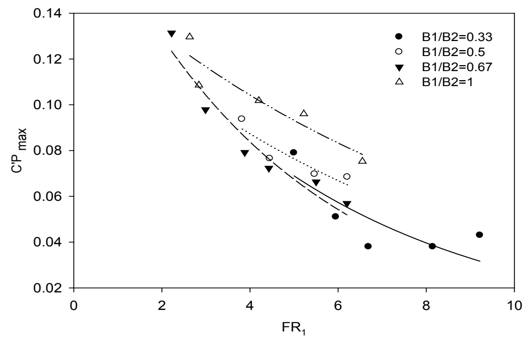


**Figure 4: Variation of Cp'max**

Table 1 indicates the maximum values of RMS dimensionless pressure fluctuations ($Cp'_{max}$) in different expansions ratio. It is observed that the $Cp'_{max}$ decreases in sudden expansions, compared with classic jump. It is influenced by the formation of side eddies and formation spatial hydraulic jump.

**Table 1: Variation of $C'p_{max}$**

| $\beta = B_1 / B_2$ | $FR_1$ | $C'p$ max |
|---|---|---|
| 0.33 | 3.2 - 9.2 | 0.04 - 0.09 |
| 0.5 | 2.3 - 6.4 | 0.06 - 0.11 |
| 0.67 | 2.7 - 6.8 | 0.07 - 0.13 |
| 1.0 | 2.6 - 6.6 | 0.08 - 0.16 |

The location of the peak value of the $Cp'$, relative to the inflow Froude number. In all cases maximum RMS dimensionless pressure fluctuations occurring at 10 < x/y1 < 30. Table 2 shows the variation of maximum negative and positive deviations from the mean pressure (Cp+, Cp-) for different expansions ratio.

**Table 2: Variation of extreme pressure**

| $\beta = B_1 / B_2$ | $FR_1$ | $C_p^+$ | $\lvert C_p^- \rvert$ |
|---|---|---|---|
| 0.33 | 3.2 - 9.2 | 0.27 | 0.27 |
| 0.50 | 2.3 - 6.4 | 0.29 | 0.33 |
| 0.67 | 2.7 - 6.8 | 0.37 | 0.37 |
| 1.0 | 2.6 - 6.6 | 0.47 | 0.53 |

## 5- Conclusions

The test results indicated that the dimensionless RMS of pressure fluctuations (Cp') decreases about 43%, 38% and 19% for expansions ratio 0.33, 0.5 and 0.67, respectively compared with classic jump.

The results showed that the maximum negative deviations ($Cp^+$) decreases about 43%, 38% and 21% for expansions ratio 0.33 , 0.5 and 0.67, respectively compared with classic jump.

The maximum positive deviations ($Cp^-$) decreases about order 49%, 38% and 31% for expansions ratio 0.33 , 0.5 and 0.67, respectively.

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