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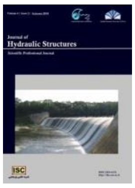

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Reducing the extent of vortices upstream of the sliding valve

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Abstract

The purpose of this research is to provide a solution to eliminate the vortices formed upstream of the sliding valve. The effect of the threshold with the geometric shapes of semi-cylinder, cylinder, pyramid and rectangular cube in different widths of 5, 7, 10, 15 and 20 cm under the sliding valve was investigated experimentally. The results of this research showed that the entry of air into the fluid leads to the formation of the vortex phenomenon in the flow profile due to the water absorption of the slide valve from the surface layers. The conservation of angular momentum at the opening of the valve causes the combination of vertical and horizontal components of the velocity near the sliding valve. The results showed that placing the threshold under the horizontal sliding valve increases the horizontal velocity of the flow. Therefore, it turns the vortex with a larger diameter into end-line vortices. Due to the insignificant effect of threshold shape on vortices, its effect was ignored.

Keywords: Sliding Valve, Vortices, Threshold, Discharge Coefficient.

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1. Introduction

Flow control and measurement in rivers and channels need more studies. Flow control structures include weirs and valves. The design and construction of these structures requires new and more practical methods. The control of water resources in the first stage is the cause of this issue. Sliding valves are one of the most important hydraulic structures that are used to control and measure the flow. The ease of installation and implementation has drawn the attention of researchers to this structure. Various hydraulic issues including discharge coefficient, energy dissipation, flow pattern have been studied by researchers. In the following, the research conducted on sliding valves has been discussed. The use of a threshold valve is one of the new structures to control the flow rate. The effect of this additional structure on energy consumption caused by hydraulic jump has been confirmed in several researches.

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Hydraulic parameters in the control structure of sliding valves in free and submerged conditions have been of interest to researchers Silva [1]. The deviation in the placement angle of the sliding valve and the use of inclined valves are among the factors affecting the discharge coefficient of this structure Shesha Prakash and Shivapure [2]. The increase in flow coefficient of inclined valves compared to vertical valves was one of the results of this research.

Daneshfaraz et al. [3] investigated the effect of the deviation angle of the sliding valve on the discharge coefficient by using the finite volume method. Increasing the angle of deviation of the sliding valve towards the upstream side increased the discharge coefficient. Investigating energy dissipation is one of the other topics on sliding valves (Abbaszadeh et al., [4]). The results showed that the use of threshold affects the characteristics of hydraulic jump.

Heidari et al [5] described the discharge coefficient without a threshold as the amount of opening of the valve and the depth of the upstream water. In this research, the parameters of height and shape of threshold were stated among the influencing factors on the discharge coefficient in the state with threshold. The effect of non-suppressed thresholds under the sliding valve on the discharge coefficient was investigated in a experimental study (Daneshfaraz et al., [6,7,8,9]). Several researches have been done on the hydraulics of sliding valves. This makes the study of this structure more important for engineers [10-16]

Vortices as a negative factor in the flow profile cause damage to the structure in a long period of time. A solution to reduce the formation of vortices has been presented in the research of Roth and Hager [17]. Their experiments were performed in a converging rectangular channel. In this research, 3 vertical anti-vortex plates with different geometries were installed upstream of the valve. As a result, the vortices were classified into 6 types. In this research, the shock waves generated at downstream were reduced by 50%. The research of Yousefian [18] is another research in this field. The opening of the sliding valve is an important parameter for the formation of vortices. In an experimental research, Norouzi et al investigated the strength of vortices. The results of this research showed that the use of the cylinder causes a decrease in the strength of the vortice Norouzi et al., [19].

The review of previous studies confirms the importance of basic design of hydraulic structures [20,21,22]. Also, there is a research gap in the field of the vortex behind the valve .It is felt to adopt a new method to increase the performance of this structure. The design of the threshold under the sliding valve as an anti-vortex element is the main goal of this research. The use of a sliding valve with a threshold has completely eliminated the eddies.

2. Materials and Methods

In the present study, a laboratory flume with a length of 5 meters, a height of 0.5 meters and a width of 0.3 meters was used. In order to create supercritical flow, a vertical valve with an opening of 4 cm was used, which was placed at a distance of 1.5 meters from the inlet tank. The flow entering the flume was pumped by two pumps with a capacity of 450 liters per minute. The current research was investigated with 4 different geometry models, which include semi-cylindrical, cylindrical, pyramidal and rectangular cube geometries. All four sills were prepared in widths of 5, 7.5, 10, 15 and 20 cm in order to study the effect of sill width on the vortices under the valve, Figure (1).

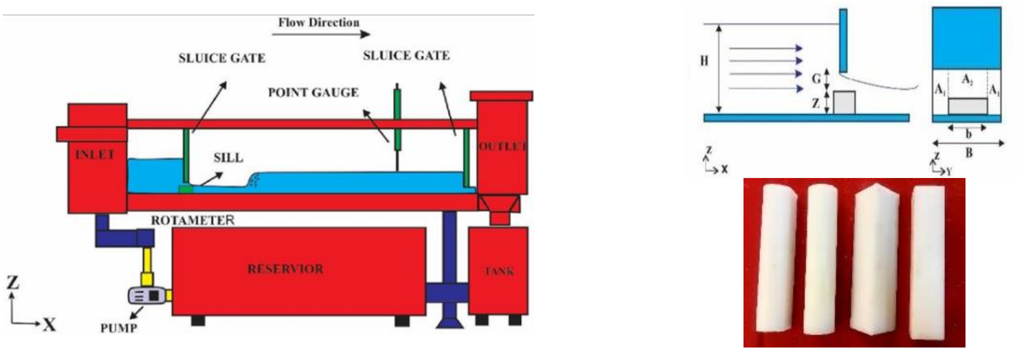


Figure 1. Schematic view of the flume and threshold used in this study

3. Results and Discussion

Changes in water depth upstream of the sliding valve were investigated using threshold and control. The figure 2 shows the percentage of upstream water depth of the sliding valve with the threshold and in the control state.

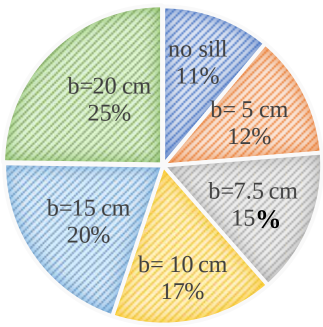
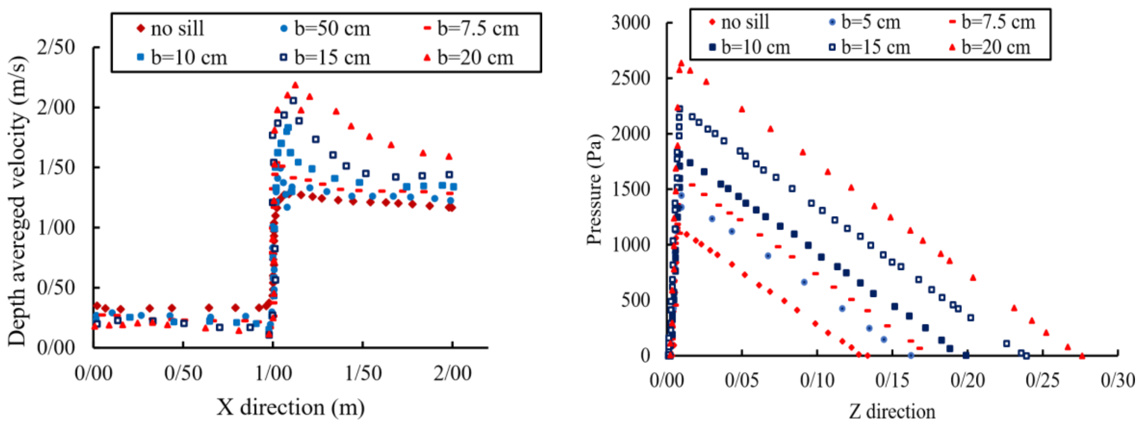


Figure 2. Upstream flow depths of sliding valve

In the present research, the changes of hydraulic parameters were investigated with the use of threshold. Therefore, in Figure (3), the effect of the threshold on different parameters has been investigated and the results have been compared with the control state.

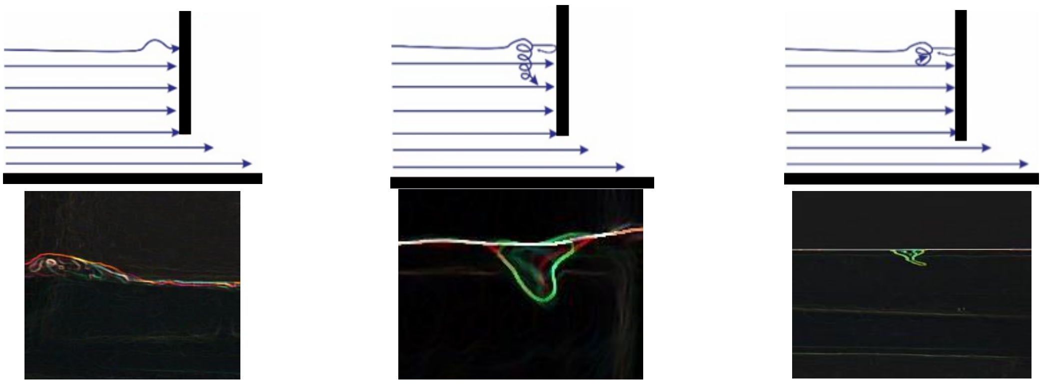


(a) **(b)**

Figure 3. Velocity and pressure changes in sliding valve

3.1. Investigating the causes and methods of vortex formation

In this research, the extent of vortices was investigated. The results of this research were compared with previous studies. In the following, the formation of vortices is discussed. These are experimental figures. Their schematic state is also shown. The repeated period of vortex formation was observed throughout the experiments. Figure (4-a) shows the turbulence of the upstream flow before the formation of the vortex. vortex is formed when air enters the fluid (4-b) and finally, after the balance between the air inside the vortex and the fluid, it gradually disappears (4-c).



(a) **(b)** **(c)**

Figure 4. Stages of vortex formation

In order to investigate the effect of the threshold on the vortices, the threshold with different geometry and widths was installed under the sliding valve. Due to the very slight changes in the appearance of the vortices in the threshold with different geometries, the effect of the geometry of the threshold on the vortices was ignored. Therefore, the vortices created in this research were divided into 4 categories according to their appearance (Figure 5).

The first category is related to the sliding valve without a threshold. In this case, the turbulence in the flow surface after hitting the valve can be clearly seen. Due to the larger opening of the sliding valve, the flow rate is low and as a result, the suction of the sliding valve is significant. The presence of a flow with high suction causes a decrease in the pressure on the surface of the flow. The low flow speed in this case causes significant penetration of air into the flow. Therefore, the formation of vortices with larger diameters was observed in this case.

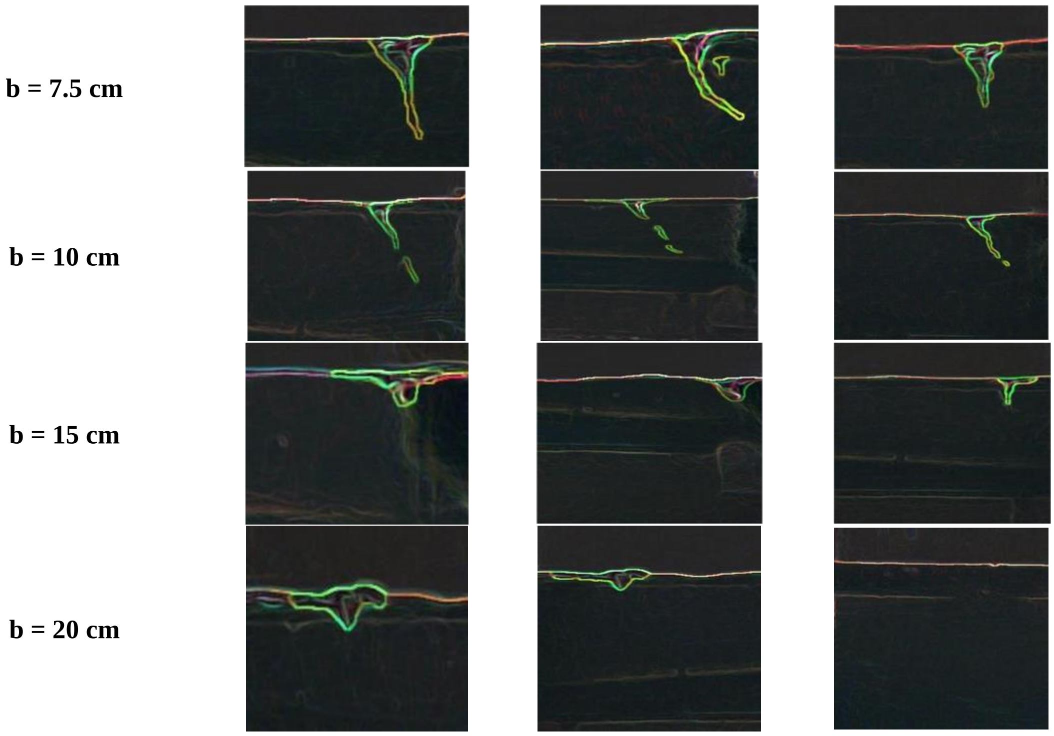


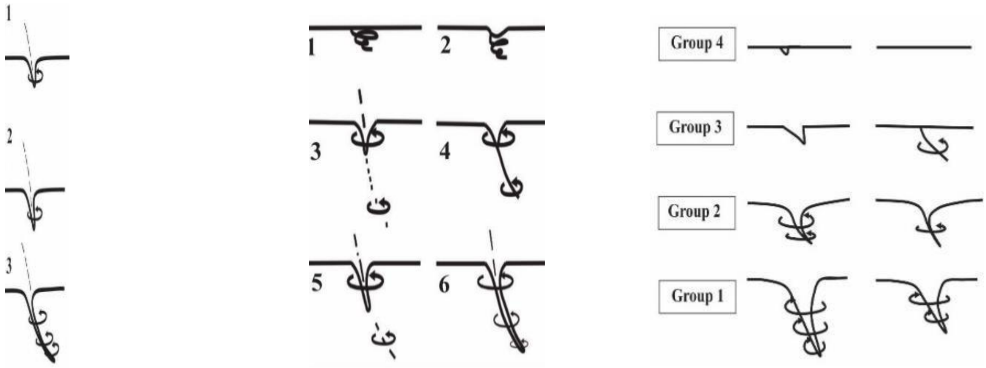
Figure 5. Classification of vortices in the present study

In the case of using a threshold with a width of 7.5 cm, vortices with a large diameter changed into vortices with a linear end. In this case, with the increase in the speed of the flow passing through the sliding valve, the horizontal speed prevailed over the flow and caused a large deviation of the end of the vortex towards the opening of the sliding valve.

In the second category, a threshold with a width of 10 cm was examined. The type of vortices formed upstream of the sliding valve was significantly changed with this threshold. Trailing vortices in the second category were gradually removed from the flow profile. Then, by placing a threshold with a width of 15 cm, the power of air penetration into the water decreased.

The use of threshold, with a larger width (b=20 cm), increasing the discharge, caused a significant increase in the water depth upstream of the sliding valve. As a result of the increase in pressure upstream of the slide valve, it led to the reduction of turbulence between water and air. Therefore, the formation of vortices decreased until the formation of vortices stopped at high flow rates. Designing new structures for hydraulic problems is of particular importance in solving engineering problems. The application of the additional structure of the sliding valve with the flange caused a reduction in the presence of vortices in the flow profile. The results showed that the use of this structure by changing the flow characteristics including depth, velocity and pressure has a positive effect on the flow profile. Because it caused the complete removal of the vortex phenomenon from the flow pattern.

In Yousefian's research, the opening of the sliding valve was the most important factor in the appearance of vortices. In Ross and Heger's research, the installation of anti-vortex plates decreased the extent of vortices. Previous studies have been done with the aim of reducing the strength of vortices. In this research, the strength of the vortices was reduced by using the threshold. Finally, with the increase in the inlet flow rate and the width of the threshold, no vortices were formed at high flow rates Figure 6.



Yousefian **Roth and Hager** **This study**

Figure 6. Comparing the extent of vortices in different researches

4. Conclusion

The present research was conducted in order to investigate the vortices formed upstream of the sliding valve along with the flow coefficient. For this purpose, the effect of the threshold in cylindrical, semi-cylindrical, pyramidal and rectangular cube geometries with widths of 5, 7.5, 10, 15 and 20 cm under the drawer was investigated experimentally. The results showed that the low water depth in the control state causes the valve to draw water from the surface layers of the flow. The opening of the sliding valve and the velocity of flow were introduced as the influencing factors on the formation of vortices. The decrease in the opening of the sliding valve by using the threshold caused an increase in the flow depth upstream of the sliding valve. Therefore, water extraction was done from the lower layers. Also, the decrease in the valve opening parameter increased the flow rate. The results showed that vortices with a larger diameter were removed from the flow profile and the strength of the vortices was reduced.

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