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EXTENDED ABSTRACT

Examining the Sediment Trapping Efficiency of Baffles with Different Shapes, Heights, and Angles, located at the Upstream of the Vortex Tube

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Introduction

The vortex tube is a structure with a slot along its longitudinal axis on top, which is installed across the width of the channel bed. This tube functions based on the gravitational force of sediment particles and swirling rotational force in the tube. It can transfer particles falling from its top slot to a specific side of the tube (Moazen and Shafai, 2003). Studies have shown the mechanism of this structure in separating the bed load. The current study used barriers with different shapes (square, triangle, and arched), heights and angles at the vortex tube upstream to increase the sediment trapping efficiency. These tests were conducted by changing the Froude number of the channel (flow hydraulic conditions). The results are provided below.

Methodology

To achieve research objectives, the following general equations were developed:

$$T_{e,}R = f\left(G_s, \frac{V^2}{gy}, \frac{D_{50}}{D}, \frac{y}{D}, \frac{\rho V y}{\mu}, \theta s, Sh, hs/y\right) \quad (1)$$

In this equation, Te is the sediment trapping efficiency or the ratio of sediment discharging from the vortex tube outlet (Qso) to the total bed sediment in the basin channel (Qsi), R is the water loss or the ratio of discharge at the tube outlet (Qvt) to the total discharge into the basin channel (Qi), V is the velocity, y is the flow head at vortex tube upstream, Gs is the density of sediment particles, g is the acceleration of gravity, D50 is the mean particle diameter, ρ is the mass per unit of water volume, D is the tube diameter, μ is the dynamic viscosity, θs is the angle of the barrier and tube to the flow, Sh is the barrier shape, hs/y is the ratio of barrier height, ρVy/μ is the Reynolds number, and V^2/gy is the Froude number.

Since the flow depth, particle size, and particle density are constant and the Reynolds number is ineffective, Equation 1 is modified as follows:

$$T_e,R = f\left(\frac{V^2}{gy}, \theta s, Sh, \frac{hs}{y}\right) \quad (2)$$

Results and Discussion

In each test, a portion of the transferred sediment entered the vortex tube and the other portion passed over it and discharged into the downstream. The input sediment was streamed into the sub-channel from the tube outlet by means of the rotational flows inside the vortex tube. The sediment flow was then volumetrically measured at the end of each test after sediment trapping. Deposited sediments at the tube downstream in the channel were also volumetrically measured during the test, using scaling containers. In this way, the input sediment into the tube was measured.

Effect of Barrier Height on Sediment Trapping Efficiency of Vortex Tube

In this study, the sediment trapping efficiency was measured by placing three square, triangular, and parabolic barriers with a distance equal to the vortex tube diameter at upstream. Moreover, each barrier was tested with three different heights to the water head, i.e., 19%, 25%, and 31%.
The 19% square barrier had positive effects for all Froude numbers and increased trapping efficiency as compared to the control. The 25% barrier increased trapping efficiency for Froude number lower than 0.78 and reduced it for higher Froude numbers as compared to the control. In the 31% barrier, trapping efficiency was lower than the control in all cases (Figure1).

Effect of Barrier Shape on Sediment Trapping Efficiency of Vortex Tube

Figure (1) shows that for Froude numbers of approximately 0.7, the 19% square and triangular barriers increased the sediment trapping efficiency by approximately 18% and 23%, respectively.

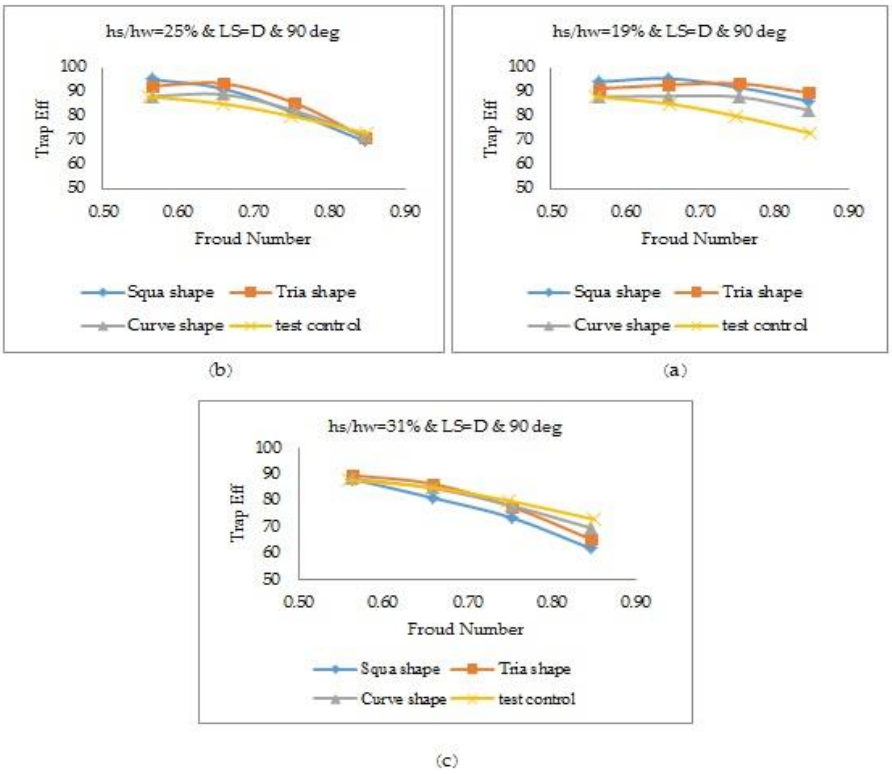

Fig. 1- The effect of the baffle shape on the sediment trapping efficiency at baffle heights a) 19%, b) 25% and c) 31%Effect of Barrier Angle at Upstream of Vortex Tube on Sediment Trapping Efficiency

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With barrier and tube angles of 90° to the flow, the sediment trapping efficiency was increased in a range between 8-30% by the square barrier, 2-27% by the triangular barrier, and 6-21% by the arched barrier with increasing the Froude number. Trapping efficiency was reduced by approximately 29% with increasing the height of the barriers. With barrier and tube angles of 60° to the flow, the sediment trapping efficiency was reduced in a range between 12-30% with increasing the Froude number.

Conclusions

Regarding the effects above of barrier angles (60° and 90°) at vortex tube upstream on the sediment trapping efficiency, barriers with height ratios of 19% and 25% to the water head increased trapping efficiency as compared to the control. The 19% square, triangular, and arched barriers increased the sediment trapping efficiency by 7-18%, 4-23%, and 0-13%, respectively. The 25% square, triangular, and arched barriers increased the sediment trapping efficiency by approximately 8%, 10%, and 5%, respectively. All 35% barriers, regardless of shape and angle, were either ineffective or reduced the sediment trapping efficiency. Moreover, the tube and square barrier at an angle of 60° to the flow were more efficient (0-13%) than at an angle of 90° in trapping sediments discharging into the basin. Regarding the effect of barrier height, the sediment trapping efficiency is reduced with increasing the barrier height, regardless of its shape. An increase in the height of the square, triangular, and arched barriers increased the sediment trapping efficiency by 6-28%, 2-27%, and 0-15%, respectively. It is worth noting that for Froude numbers of approximately 0.7, the 19% square and triangular barriers increased the sediment trapping efficiency by approximately 18% and 23%, respectively. In addition, the 25% square and triangular barriers increased the trapping efficiency by 8% and 10% for Froude numbers less than 0.6 and between 0.6-0.8, respectively. All barriers, regardless of their shapes, had negative effects on the trapping efficiency for the Froude numbers higher than 0.8. The 31% barrier also showed no positive effect on the trapping efficiency.

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