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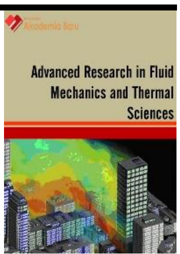

Effects of Floor Splitter Height on the Effectiveness of Swirl Angle Reduction in Pump Intake

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ABSTRACT

Floor splitter has been implemented in many applications involving submersible pumps with sump intake and proven to be effective in correcting the adverse flow at the pump intake entrance. However, further study on the influence of its dimensions on the effectiveness of vorticity reduction should be carried out to get the optimal design. In this study, three floor splitters with different heights were installed under a bell-shaped pump intake and their effectiveness in reducing swirl angle in the intake pipe were evaluated using a swirl meter. Three different inflow conditions were introduced to assess the floor splitter performance in various sump geometries. Results showed that the biggest reduction in swirl angle was displayed by the floor splitter with the greatest height. In the case where inflow condition was set by a diverging wall, all floor splitters produced least reduction in swirl angle due to the existence of induced surface vortex and the fact that floor splitter performed at its best with the existence of sub-surface vortex.

1. Introduction

Pumping station is one of the most important components in an irrigation or a drainage system. It controls the water flow so that the system could deliver its function and intended design. In a pumping station, water is drawn from a sump and pumped through the outlet into the water supply line. Sump condition can affect the output of the pump and ultimately the pump performance. Inappropriate design of sump can generate vortices at the pump intake which brings detrimental effects, although some applications utilizes vortex to their advantage [1,2,3]. Adverse hydraulic condition in the sump can lead to problems such as excessive vibration, cavitation, abnormality of flow and imbalance loading at the pump impeller [4,5]. Melville *et al.,* [6] pointed out parameters related to the condition of the sump that affects pump performance, namely approach channel geometry, critical submergence of the pump intake pipe and sump geometrical features such as floor

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clearance, bay width and backwall clearance. Many researches have been conducted in the past decades to develop a strong foundation for the understanding of pump sump hydraulics either through experimental approach [7-11] or numerical approach [12-16].

The study on pump sump flow has led to the design of vorticity control measure called the anti-vortex device (AVD). There are several types of AVD proposed in the American National Standard Institute – Hydraulic Institute (ANSI-HI) standard for Rotodynamic Pumps [17] and one of them is the floor splitter. The design of floor splitter, however, is still considered a concept and there is no definitive dimension proposed in the standard, although some study showed that the floor splitter dimension affects the outcome of vorticity reduction in pump intake sump [18-20]. Information regarding on this type of AVD is limited in the literature despite its popularity in the industry [18]. In this study the effects of floor splitter height on the vorticity reduction focusing on the swirl angle at the pump intake will be discussed.

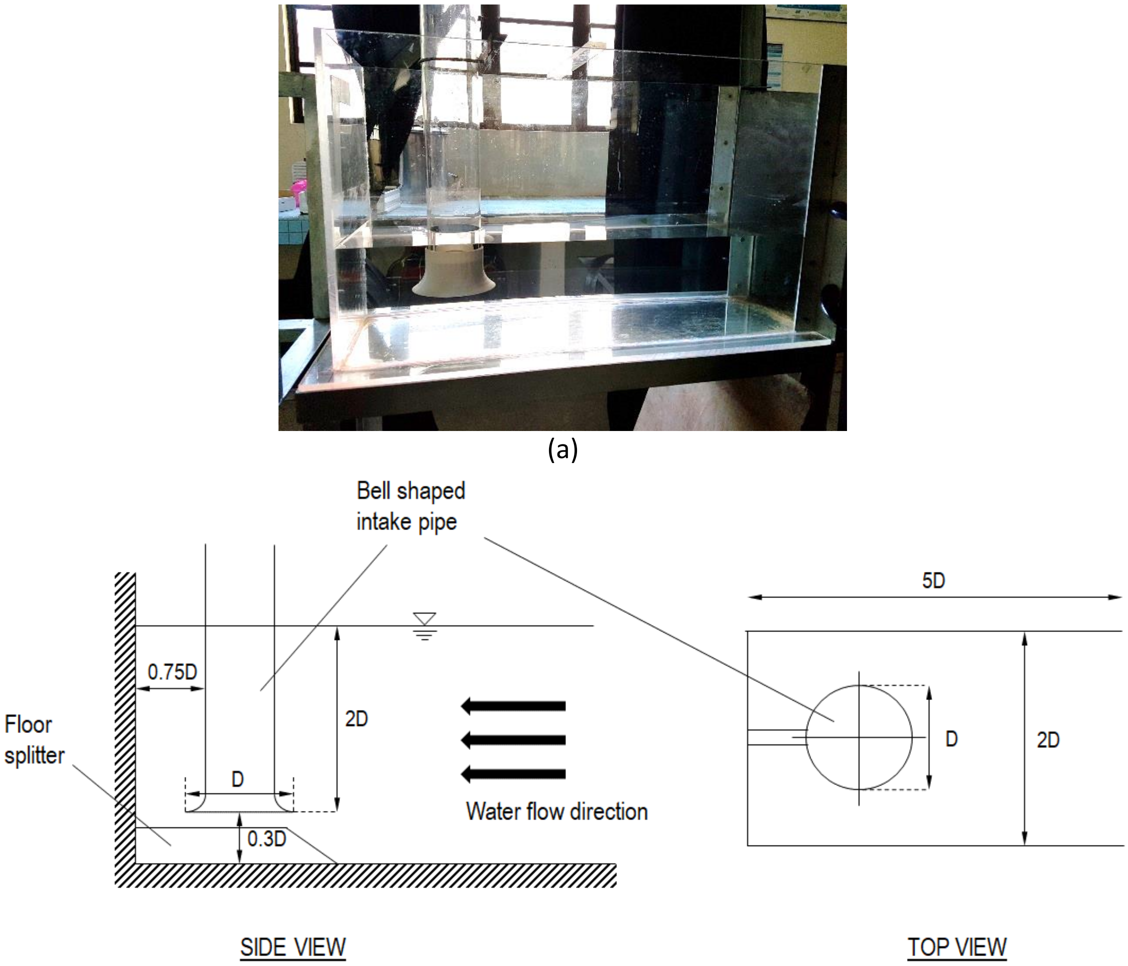
2. Methodology

A scaled pump sump model was fabricated to study the effect of vorticity reduction of different floor splitter designs where a transparent acrylic tank was connected to a steel flume as illustrated in Figure 1(a). All main dimensions were normalized by the diameter of the entrance of the bell-shaped intake pipe which was 150 mm. The selection of dimensions indicated in Figure 1(b) was based on the dimensions recommended in ANSI-HI 9.8 (2012) standard. The submergence of the intake pipe is one of the determining factors of the vortex type which could form in the sump and it is set in this study to prevent the occurrence of surface vortex and therefore limits the possibility to only the occurrence of eventual sub-surface vortices. The flow rate of the pump was set to 0.0094 m^3/s which was calculated using similitude principle with the prototype pump to which the model in this experiment was scaled and the velocity of the flow in the sump was 0.09 m/s. An instrument used to measure the swirl in the intake pipe called a swirl meter was installed in the pipe according to ANSI-HI 9.8 (2012) standard as shown in Figure 2. The intensity of the swirl is measured by the amount of swirl angle in the flow which can be calculated using the following equation:

$$Swirl\ angle\ \theta = tan^{-1}\left(\frac{\pi d n}{u}\right), \tag{1}$$

where u is the average axial velocity at the swirl meter, d is the diameter of the pipe at the swirl meter (in this study the value of d is 94 mm) and n number of revolutions per second of the swirl meter. According to ANSI-HI 9.8 (2012) standard the swirl angle should be less than 5° to reduce pressure loss in the suction of the pump.

Three floor splitters of the same shape but with different heights were selected for the study as depicted in Figure 3. A condition where no floor splitter installed under the intake pipe was also measured in the experiment to determine the intensity of the swirl to be reduced from the use of the floor splitters and as a control. The experiment was conducted by setting the flow at the entrance of the transparent tank in three flow conditions; one is without any constriction in the channel and two are with constrictions which resemble the typical environment of the actual pump sump on site. The details of these configurations are presented in Figure 4.



(a)

(b)

Fig. 1. A scaled single bay pump sump model, (a) Experimental rig (b) schematic dimensions

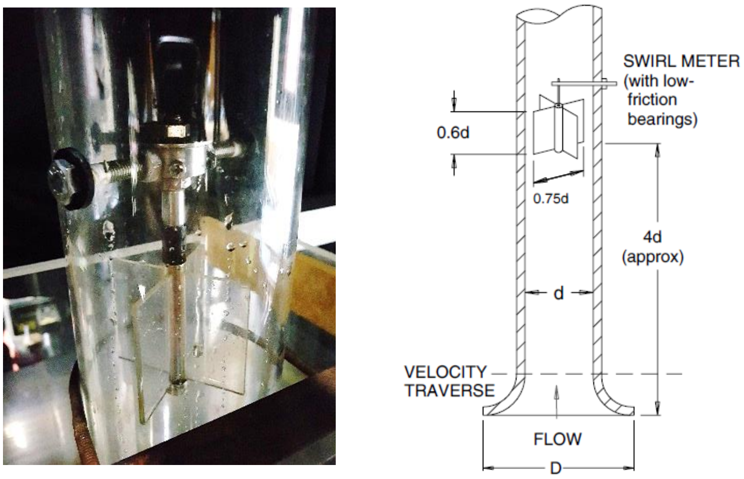


Fig. 2. Swirl meter in compliance with ANSI-HI 9.8 (2012) [14]

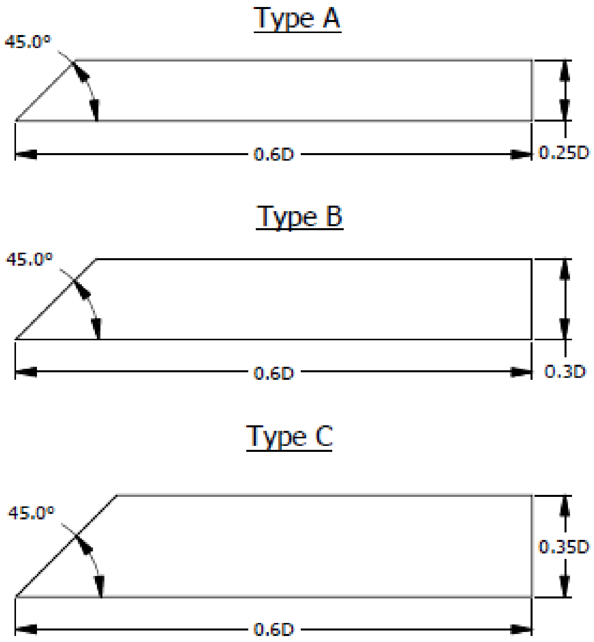
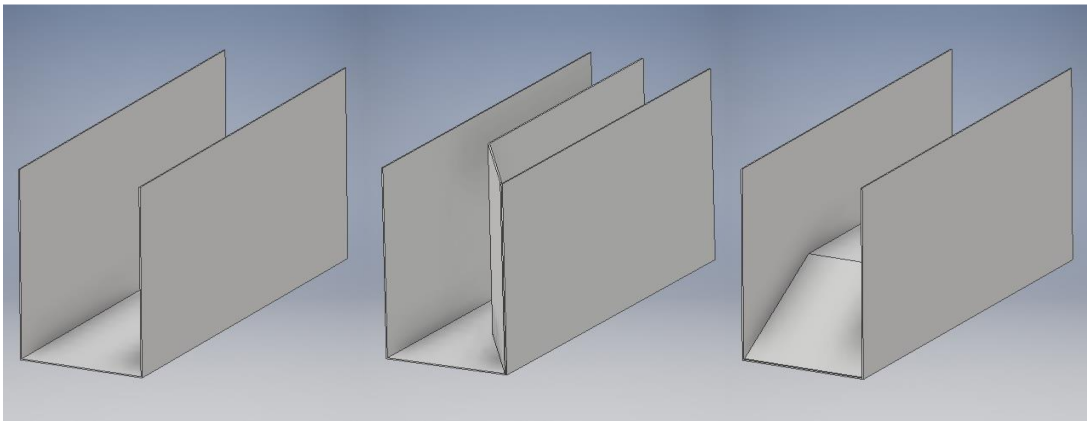


Fig. 3. Floor splitters with different heights



(a) (b) (c)

Fig. 4. Flow profile settings at the entrance of the transparent tank a) no flow constriction, b) diverging wall with vertical plane inclined at 30°, c) floor slope with horizontal plane inclined at 30°

3. Results

3.1 Swirl Angle in the Intake Pipe

The swirl angle captured by the swirl meter installed in the intake pipe of each case were compared and the results are discussed in the next section. The measurements were average values in which the readings were taken continuously during consecutive intervals of 10 seconds covering a period of 10 minutes in compliance with ANSI HI 9.8 (2012) standard.

3.1.1 Flow in channel with no constriction

Results in Table 1 shows significant difference in swirl angle value for every floor splitter installed where floor splitter type A reduced the swirl angle, which was measured at 9.76 degrees when not installed with floor splitter, by 11% but the residual swirl angle was still greater than the allowable angle which is 5 degrees. On the other hand, floor splitter type B and C managed to reduce the swirl angle to below 5 degrees where floor splitter type C showed the largest reduction which was 71.1%.

The difference between the floor splitter types were their heights and from the results it can be concluded that bigger floor splitter heights reduces swirl angle more effectively. This theory can be based on the swirling motion that previously occurred at the floor of the sump directly beneath the intake pipe had been obstructed by the floor splitter and higher splitters broke greater amount of swirl as shown in Figure 5. The results also proved that floor splitters are the type of AVD which can effectively cure hydraulic problems caused by swirls and vortices originated from the floor.

Table 1
Values of swirl angle for each floor splitter type in channel flow with no restriction

Floor splitter	Swirl angle θ	Reduction
No floor splitter	9.76°	-
Type A	8.68°	11.0%
Type B	3.45°	64.7%
Type C	2.82°	71.1%

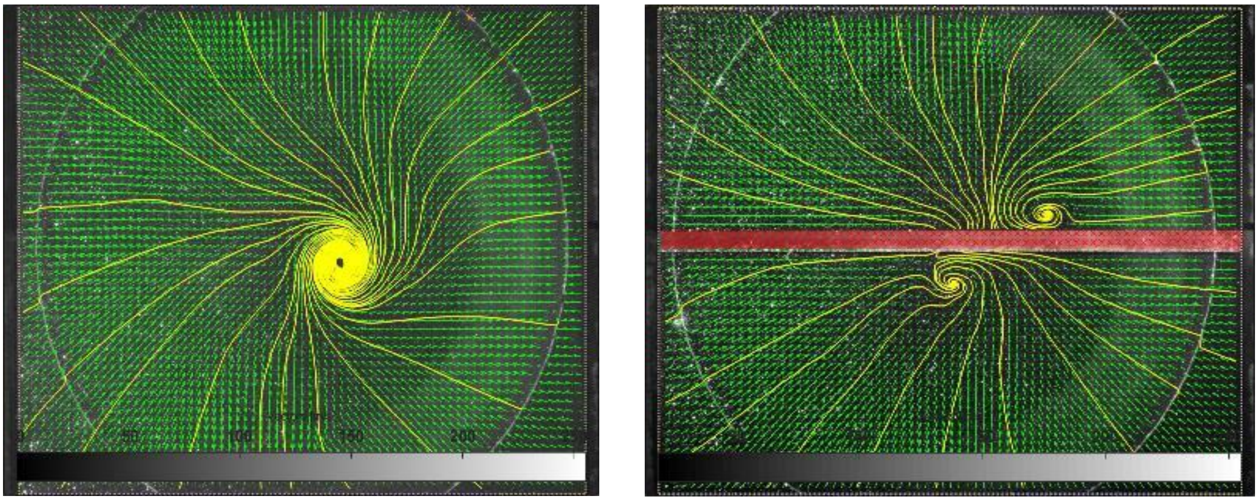

(a) (b)

Fig. 5. Streamline plot showing the large vortex core (a) split into two smaller vortices (b) by the floor splitter

3.1.2 Flow in channel with diverging wall

Results in Table 2 indicate different results from the condition with no constriction in the flow. All floor splitters produced only a small portion of reduction in the swirl angle although the trend was similar with the previous case in which floor splitter type C showed the highest reduction followed by type B and type C. The diverging wall with 30° inclination angle (Figure 4(b)) created a rotating motion in the flow called pre-swirl before approaching the intake pipe and the pre-swirl had developed into surface vortex as it approached the intake. The occurrence of surface vortex introduced a counter rotation effect to the vortex originated from the floor as it approaches the pump inlet as shown in Figure 6 thus reducing the swirl angle in the pipe. This was reflected in the result where the swirl angle, which was 9.76° previously, reduced to 5.94° for the case in which no splitter was installed. The result also indicated that floor splitters are not effective to reduce swirls and vortices in the presence of surface vortices based on the relatively low amount of reduction for each type of floor splitter.

Table 2
Values of swirl angle for each floor splitter type in channel flow with diverging wall

Floor splitter	Swirl angle θ	Reduction
No floor splitter	5.94°	-
Type A	5.45°	8.3%
Type B	5.09°	14.3%
Type C	4.13°	30.5%

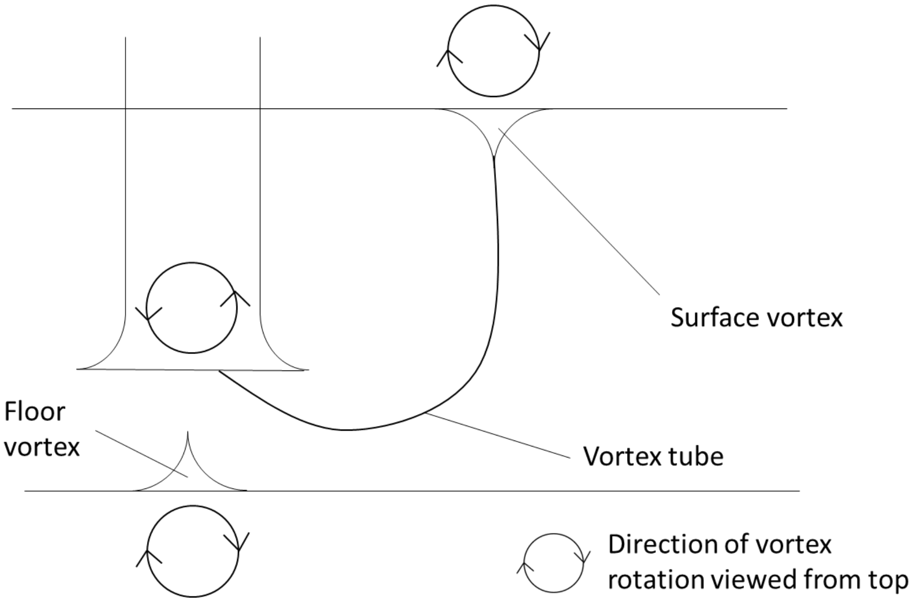


Fig. 6. Indication of rotation direction of the vortices generated at the pump intake

3.1.3 Flow in channel with floor slope

Table 3 shows the results of swirl angle measurement for the flow in the channel with sloped floor (Figure 4(c)). The results are similar with the case of channel flow with no restriction where all splitter types displayed reduction in swirl angle. In this case the swirl angle of the flow without the installation of floor splitter had increased to 10.93° due to the incorporation of floor with inclination angle of 30°. This configuration caused the velocity gradient to increase significantly as the water descends the inclined floor as depicted in Figure 7 and thus increases the strength of floor vortex. The swirling motion under the pipe had therefore been accelerated and thus produced greater swirl angle at the swirl meter. Under this condition, the floor splitters reacted accordingly and managed to reduce the swirl to certain amount. As predicted, the floor splitter of type C displayed the biggest amount of reduction at 66.9% followed by type B splitter with 59.3%; both have successfully kept the swirl angle under 5°. Type A floor splitter was yet to effectively reduce the swirl angle but performed better compared to its performance in the previous setting. The factor behind these results in this case may reflected by the same factor in the no constriction case.

Table 3
Values of swirl angle for each floor splitter type in channel flow with floor slope

Floor splitter	Swirl angle θ	Reduction
No floor splitter	10.93°	-
Type A	8.28°	24.2%
Type B	4.45°	59.3%
Type C	3.62°	66.9%

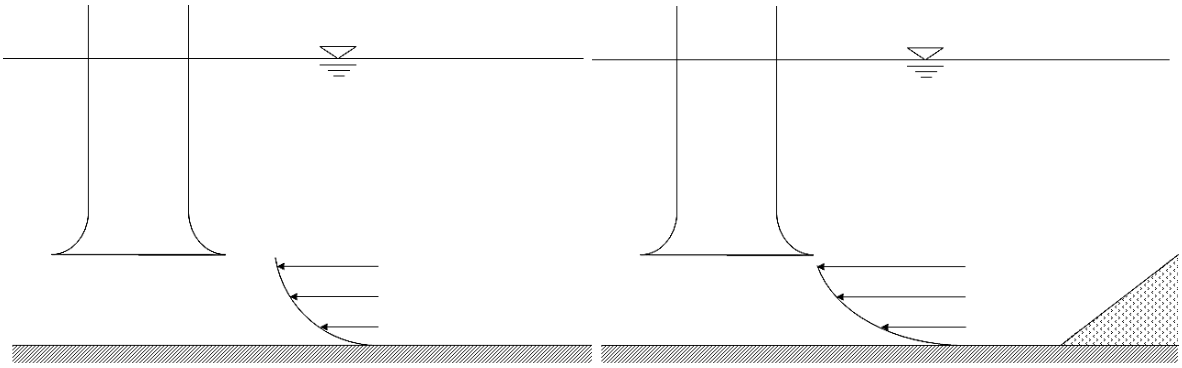


Fig. 7. The velocity gradient increases for the inclined floor case compared to the case without flow restriction

4. Conclusions

The experimental data to study the effectiveness of various floor splitter dimensions in reducing swirl angle in an intake flow of a pump system in a pump sump by the measurement of swirl angle in the intake pipe was conducted. Results showed that the height of a floor splitter played a major role in swirl reduction where the greater the height of a floor splitter, the more effective the swirl reduction ability will be. Floor splitter with the height greater than 0.3D has been successful in keeping the swirl angle in the intake pipe below the maximum allowable value which is 5°. The effectiveness of floor splitter also depends on the condition of the boundary of the channel in which channel with diverged walls will induce surface vortices and thus made floor splitter less effective.

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