Effect of spillway profiles in air-water interactions using ANOVA

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ABSTRACT

This paper discusses the use of Taguchi method for minimizing the penetration depth of air in water in open channel flow passages.Spillways are protection devices in a weir analogous to a safety valve in a steam generator. Numerous failure of weir have been reported due to insufficient capacity or improper design of spillway. Departure of flow lead to huge blow velocity of the decelerating water, which would lead to the significant entrainment of air in water. This paper describes the effect of spillway profile in air-water interactions in open channel flow passages using the Analysis of Variance(ANOVA) tool.

KEY WORDS: Air Entrainment, Flow Separation, Flow rate, Spillway.

1. INTRODUCTION

Spillways are frequently used to amend the flow of rivers to avoid floods, measure flow and also in nuclear reactors for unvarying cooling of the reactor. The theory of spillway structure allow stabilization of the water free level and avoids discrepancy in free level of water beside the flow passage as a function of flow rate as shown in Figure 1. The foremost crisis in the spillway is the profile of crest. The criterion need to be fulfilled are: (i) no flow departure from the crest and (ii) unvarying circumferential flow to let alone flow asymmetry in the flow passage. The profile of the spillway has to be optimized for least thickness and altitude. This assume crucial significance in case the spillway has to be curved inside to avoid flow separation.

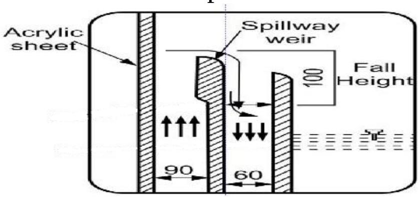

Fig.1. Spillway system

Profile of the Tested: The profile of the spillway was designed and manufactured to check the characteristics and the air entrainment studies. The profile is 1m length, 0.15m height and 0.03m width. The various spillway profiles such as teak wooden profile bulged at the centre, bulged at the bottom and profile with grooves were experimented for air entrainment phenomenon. The various profiles are shown in Figure 2-4. Water was used as the working fluid.

Fig.2. Centre bulge profile

Fig.3. Bottom bulge profile

Fig.4. Spillway profile with grooves

Table.1. Operating parameters and their levels

Operating parameters	Unit	Level 1	Level 2	Level 3
Profile		Bottom bulge	Centre bulge	Grooved profile
Flow rate	LPM	108	360	600
Fall height	mm	100	400	700

For minimizing the penetration depth of air in water, the above process parameters shown in Table 1 are chosen for finding the best combination using ANOVA.

Table.2. Parameters with different combinatins

	Fall height (mm) C	Flow rate (LPM)		
		108 B_1	360 B_2	600 B_3
Bottom bulge A1	100 C_1	170	190	350
	400 C_2	180	300	360
	700 C_3	150	250	380
Centre bulge A2	100 C_1	150	190	230
	400 C_2	180	250	300
	700 C_3	130	260	300
Grooved profile A3	100 C_1	150	210	260
	400 C_2	190	300	380
	700 C_3	130	260	380

Table.3. Parameters and their levels with their responses

Expt No	Profile (A)	Flow rate (B)	Fall height (C)	Response Pnetration depth Y	η
1	1 (A_1)	1 (B_1)	1 (C_1)	170	-44.608
2	1 (A_1)	2 (B_2)	2 (C_2)	300	-49.54
3	1 (A_1)	3 (B_3)	3 (C_3)	380	-51.59
4	2 (A_2)	1 (B_1)	2 (C_2)	180	-45.105
5	2 (A_2)	2 (B_2)	3 (C_3)	260	-48.3
6	2 (A_2)	3 (B_3)	1 (C_1)	230	-47.23
7	3 (A_3)	1 (B_1)	3 (C_3)	130	-42.238
8	3 (A_3)	2 (B_2)	1 (C_1)	210	-46.444
9	3 (A_3)	3 (B_3)	2 (C_2)	380	-51.54

The calculations to arrive S/N ratios are given in the following equation

$\eta=\log_{10} Y_i^2$, $\eta=\log_{10} 170^2$, $\eta_1= -44.608$, $\eta_2= -49.54$, $\eta_3= -51.59$, $\eta_4= -45.105$, $\eta_5= -48.3$, $\eta_6= -47.23$, $\eta_7= -42.238$, $\eta_8= -46.444$, $\eta_9= -51.54$,

Effect of Factor A with level 1

$mA_1=1/3(-44.608-49.54-51.59)= -48.58$, $mA_2= -46.878$, $mA_3= -46.574$, $mB_1= -43.992$, $mB_2= -48.095$, $mB_3= -50.12$, $mC_1= -46.094$, $mC_2= -48.728$, $mC_3= -47.39$.

The average response in terms of S/N ratio of each level of all factors for minimization is given in Table 4.

Table.4. Average response in terms of S/N ratio for minimization

Factor	Level 1	Level 2	Level 3	Difference	Rank
Profile (A)	-48.58 **(Min)**	-46.878	-46.574	1.826	3
Flow rate (B)	-43.992	-48.095	-50.12 **(Min)**	6.123	1
Fall height (C)	-46.094	-48.728 **(Min)**	-47.39	2.634	2

Hence the best combination is $A_1B_3C_2$. Best combination is A_1- Bottom bulge, B_3-600 (LPM), C_2-400 mm.

3. RESULTS AND DISCUSSION

The various spillway profiles such as centre bulge profile, bottom bulge profile and profile with grooves were tested for penetration depth of air bubbles in water for various flow rates. The flow rates are 108 LPM, 360 LPM and 600 LPM. It is found from the Taguchi method that the bottom bulge profile with flow rate of 600 LPM at a fall height of 400 mm gives comparatively less penetration depth of air bubbles indicating that it is acceptable.

4. CONCLUSION

For centre bulge profile and profile with grooves, the depth of penetration is found to be high and hence that profiles are not suggested for air entrainment studies. Hence it is suggested to use bottom bulge profile and for air entrainment studies.

REFERENCES

Cros A, Del Beccaro R, and Aita S, Thermal protection of the rapide 1500 main vessel by means of a spillway, Proc. of Smi RT - 9, Lausanne, Switcherland, E, 1987, 73-80.

Eguchi Y, and Tanaka N, Fluid elastic vibration of flexible overflow, JSME Int. Journal, 33 (3), 1990, 323-329.

Hubert Chanson, Predicting oxygen content downstream of spillways and waterways, Civ. Engrs Wat. Marit. and Energy, UK, 112, 1995, 20-30.

Jahansen S.T, Svend Graadahl and Thomas F. Hagelien, Entrainment of inclusions from the dross in stirred reactors for melt treatment, Applied mathematical modeling, 28, 2004, 63-77.

Moghiman M, Hashemi T, Zahmatkesh I, Daghighi Y, Effects of particle size and equivalence ratio on cyclone gasification of wood powder, J. Energy Inst., 80, 2007, 29–34.

Patwardhan Y, and Johnson H, CFD simulation of jet mixing in water tanks, Journal of spacecraft and rockets, 45 (6), 2008, 1149-1164.

Saddington AJ, Lawson NJ, and Knowles K, Numerical Predictions and Experiments on Supersonic Jet Mixing from Castellated Nozzles, ICAS 2002 Congress, UK, 2002.

Shen J, Wang XS, Garcia-Perez M, Mourant D, Rhodes MJ, Li CZ, Effects of particle size on the fast pyrolysis of oil mallee woody biomass, Fuel, 88, 2009, 1810–1817.