**Bulletin of Environment, Pharmacology and Life Sciences**
Bull. Env. Pharmacol. Life Sci., Vol 5 [5] April 2016: 19-26

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

**ORIGINAL ARTICLE** **OPEN ACCESS**

# Numerical Modeling of the Flow by Investigating the Effects of Opening the Gates on the Hydraulic Flow and Jet Trajectory

**Mohammad Kakeshpour[1], Arman Bahadori Birgani *[2], Mohammadjavad Johardar[2], Nader Naderi[3], Mehdi Bonyadi[4]**
[1]Master Grade – Civil Engineering, Islamic Azad University – Islamshahr Branch, Iran
[2]Department of Civil Engineering, Islamic Azad University, Dezful Branch, Iran
[3]Young Researchers and Elite Club, Islamic Azad University, Islamshahr Branch, Iran
[4]Department of Civil Engineering, Islamic Azad University, Hamedan Branch, Iran
*Corresponding author: bahadori_arman@yahoo.com

**ABSTRACT**
*The importance of dams' reservoirs management makes it necessary to use gates on the spillways. This changes the hydraulic flow on the chute spillway with ogee crest and flip bucket using VOF and RNG turbulence model. Investigating the effects of four openings as 15, 30, 45, and 100%, applied by the radial gate shows that the increase of openings leads to the increasing trend of speed and depth and potential of cavitations on the spillway. Moreover, in some openings with low discharge, due to the development of lower discharge than the sweeping discharge, it is possible for the flow to accumulate on the spillway and its hydraulic effects should be taken into account. In addition, trajectory jet modeling of the flip bucket indicates low error of the length and maximum height of the jet and thus the use of Flow-3D is recommended in predicting the downstream protection of flip bucket. Besides, two equations are presented on the relationship between the length of jet trajectory, maximum height, discharge and the rate of opening.*
***Keywords**: radial gate, turbulence model (RNG), k-ε, cavitations number, jet trajectory*

Received 03.02.2016 Revised 14.03.2016 Accepted 29.03.2016

## INTRODUCTION

An important and noticeable point in designing spillways is that the flow on the spillways is generally supercritical with high speed and energy. One of the ways of energy dissipation is to create flip bucket particularly at the end of chute spillways [1]. In recent years due to the introduction of modern and precise methods of numerical calculation of equations as well as advanced computers to do calculations, it is possible to design such complicated structures through numerical methods. The review of conducted studies shows that although numerical-laboratory studies have been conducted on the hydraulic characteristics of flow in the chute spillways with the ending cup and acceptable results have been achieved, further research is needed on the effect of opening on the hydraulic flow in the spillway and jet through flip bucket. Issues such as management of dams' reservoirs, which make it necessary to use gates over the spillways, will change hydraulic flow over the spillway and this research aims to investigate these changes.

## MATERIALS AND METHODS

The reservoir dam of Balarud is a reservoir dam with clay core and additional facilities which is located in Khuzestan Province 27 km off the north of Anidimeshk. In Balarud dam ogee spillway with control gate is used. Throughput capacity of the Balaroud River is 870m3/s and the highest flow of the probable maximum flood (PMF) is 3851 m3/s [2].

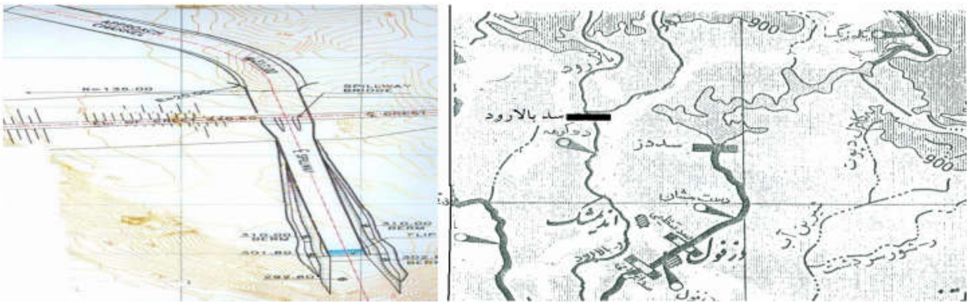


*Figure 1: Position of Balarud Dam*

Physical model of Balarud Dam spillway which is an ogee gated one with chute and flip bucket was made by Mehri *et al*. [3] using Plexiglas material on a scale of 1:110 and was installed in the flume of hydraulic models laboratory of Water Engineering Faculty of Shahid Chamran University.
The experiments were carried out by making 5 different flows on the scale of 1:110 and in accordance with the actual situation by measuring parameters such as pressure, speed, rate of cavitation at different times in 20 points along the spillway as well as the length and maximum height of jet trajectory through flip bucket. The physical model of Balarud spillway is displayed in Figures 2, 3 [3].

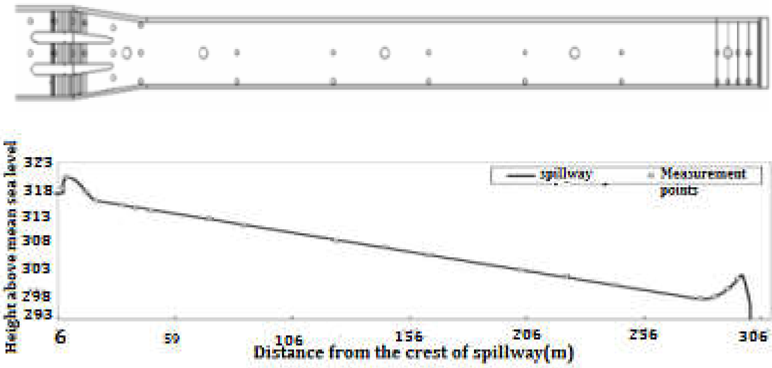


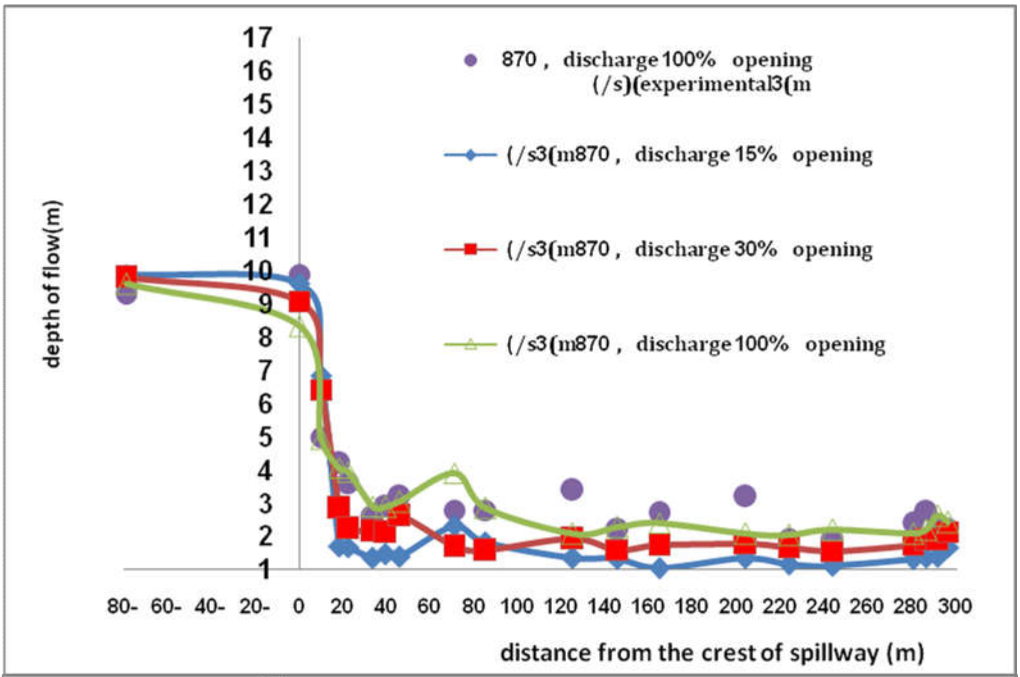

*Figure (2): Sections coordinates in physical model of spillway*

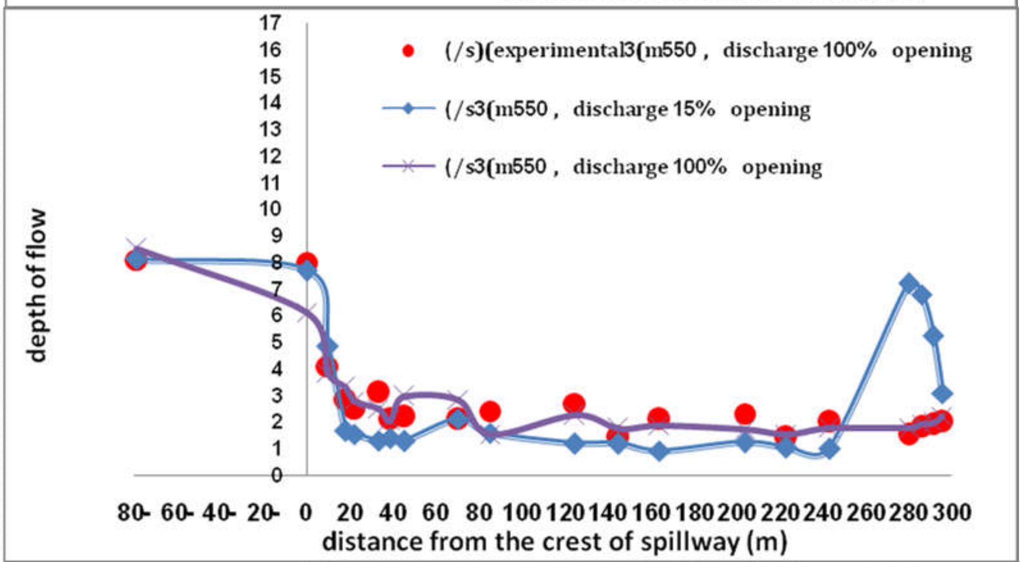
*Figure (3): Laboratory model of Balarud Dam spillway*

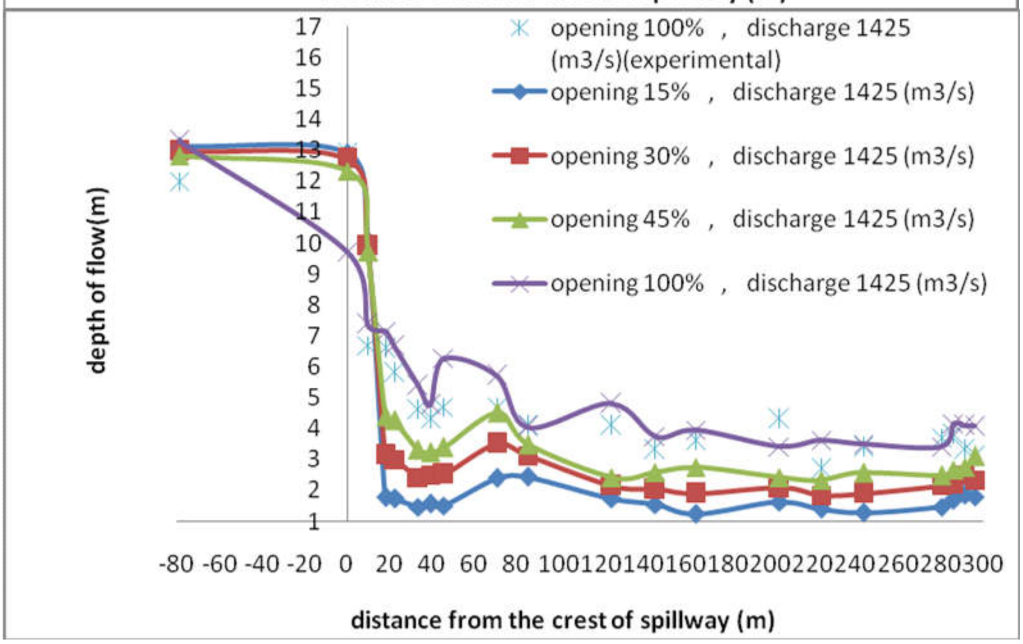
Through debugging and confidence level test (t-student) on hydraulic parameters, the results indicate confidence level of over 70% and 15% error of the parameters.

## RESULTS AND DISCUSSION

Figure 4 shows the results of a survey on the depth affected by the openings. Serious changes are observed in the distance range of 39.3 to 163.3 m from the crest which are known as rooster tail waves (waves which are made by the spillway base and which gradually dissipate along the chute). In flip bucket with the flow of 550 m3/s and 15% opening of the gate, the flow has not been thrown due to lower flow discharge than sweeping discharge, and the flow accumulation has occurred. Sweeping discharge is the minimum discharge for creating jet trajectory and the range of creating sweeping discharge is set to be 285 m3/s. It should be noted that water level at upstream side of spillway is assumed to be constant in all modes of opening.


870 , discharge 100% opening (/s)(experimental3(m
(/s3(m870 , discharge 15% opening
(/s3(m870 , discharge 30% opening
(/s3(m870 , discharge 100% opening
depth of flow(m)
80- 60- 40- 20- 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
distance from the crest of spillway (m)


(/s)(experimental3(m550 , discharge 100% opening
(/s3(m550 , discharge 15% opening
(/s3(m550 , discharge 100% opening
depth of flow
80- 60- 40- 20- 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
distance from the crest of spillway (m)


opening 100% , discharge 1425 (m3/s)(experimental)
opening 15% , discharge 1425 (m3/s)
opening 30% , discharge 1425 (m3/s)
opening 45% , discharge 1425 (m3/s)
opening 100% , discharge 1425 (m3/s)
depth of flow(m)
-80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
distance from the crest of spillway (m)

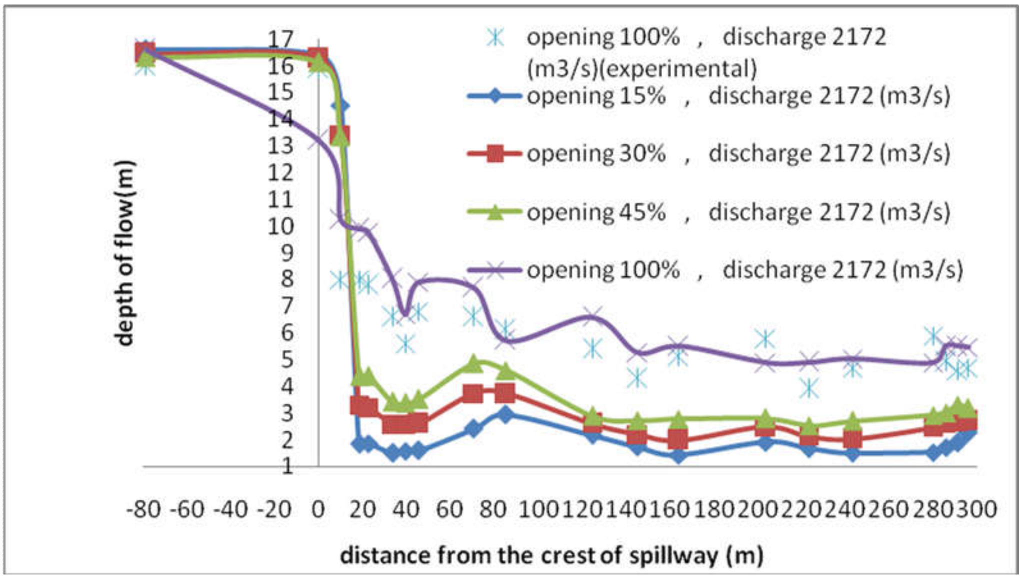
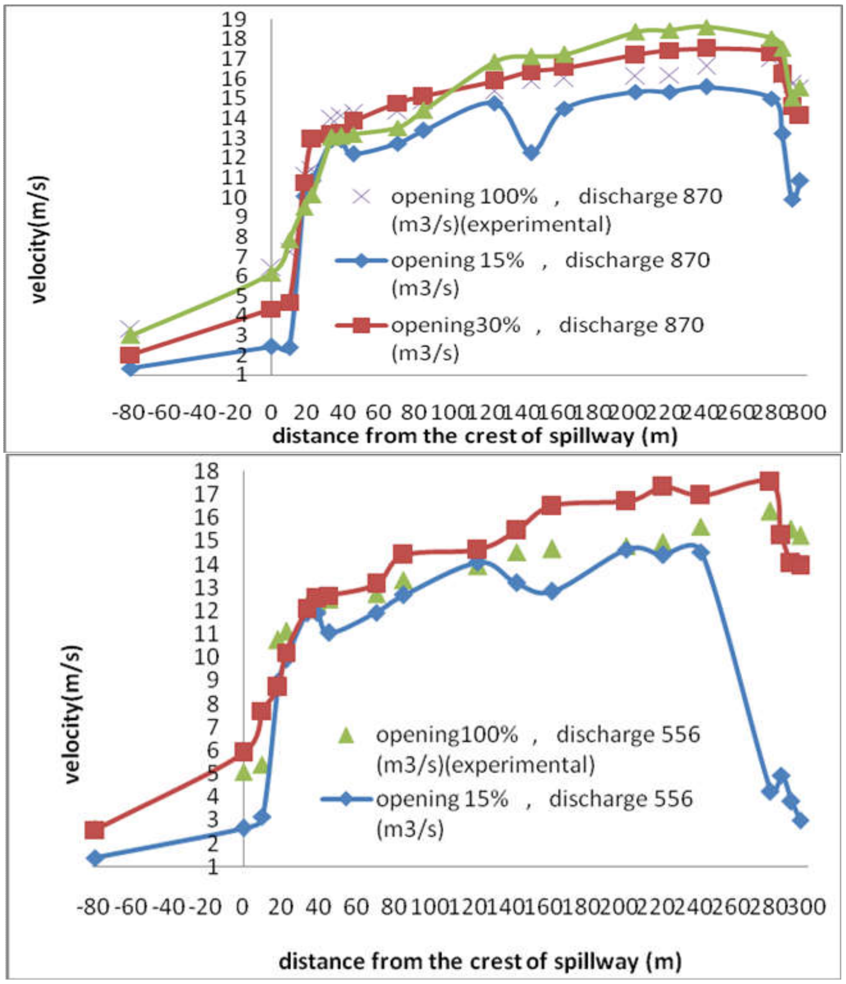



***Figure (4): Comparison of flow depth along the spillway in openings of 15, 30, 45 and 100% in 4 discharges***

Figure (5) displays the rate of speed changes for 5 discharges and except for the discharge of 550 m3 in the opening of 15%, the rate of speed changes is uniform. The increase of speed in the distance of 45 m away from the spillway crest is due to the end of bridge legs and the increase of speed continues to the ending point of chute and then it reduces at the end of spillway due to the existence of flip bucket.



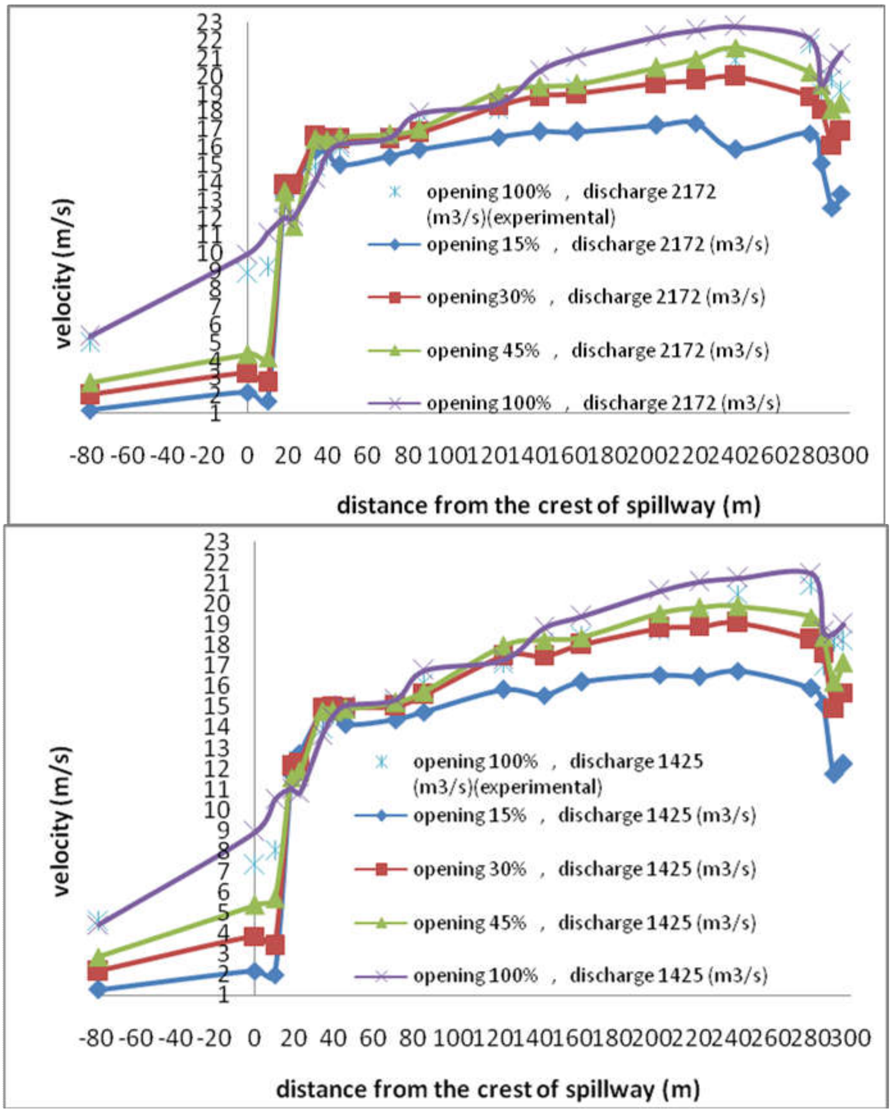
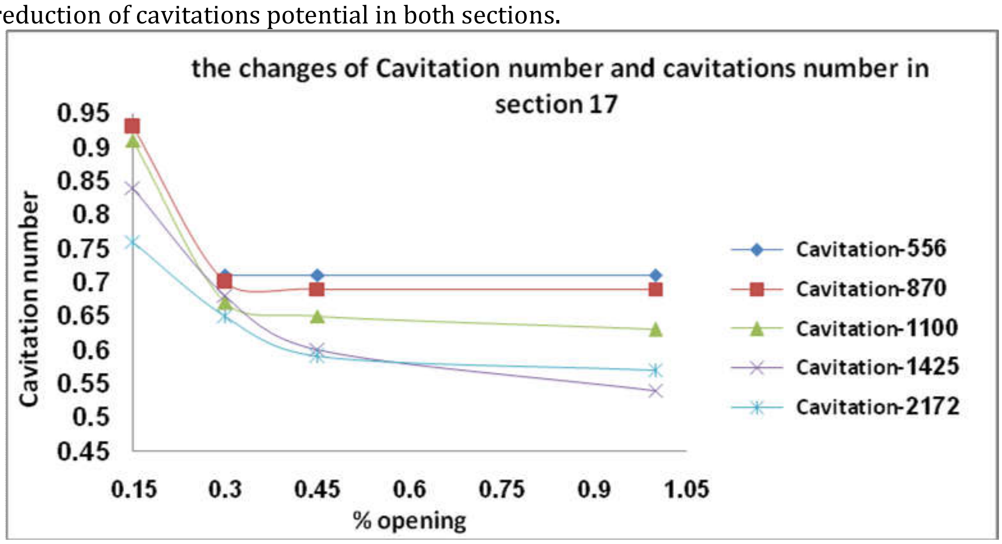



***Figure (5): Comparison of flow speed along the spillway in the 4th opening and 4 discharges***

According to the results, the initial section of the (section17) has the most critical condition in terms of cavitation potential. Figure (6) investigates the changes of speed and cavitations number for 4 states of opening in the two points. As seen in Fig. 7,the increasing trend of speed can be observed for the opening and the reduction of cavitations potential in both sections.



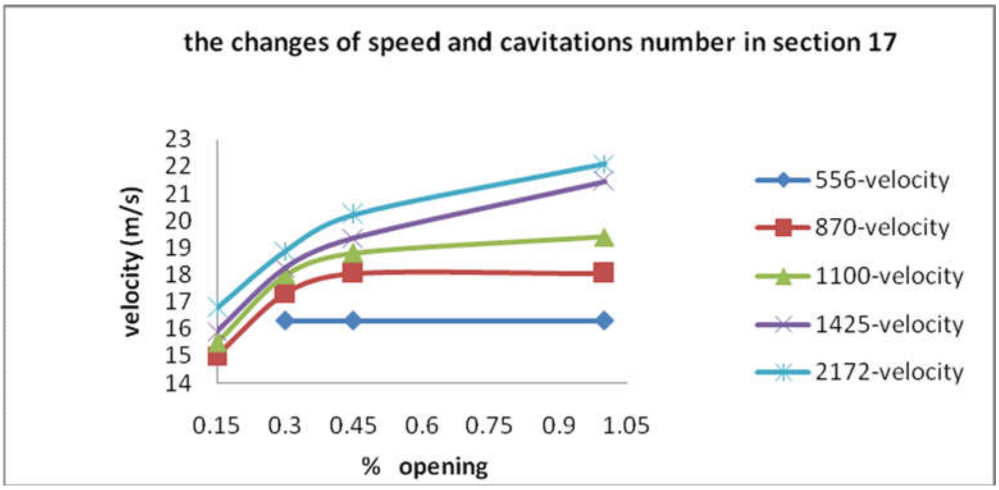


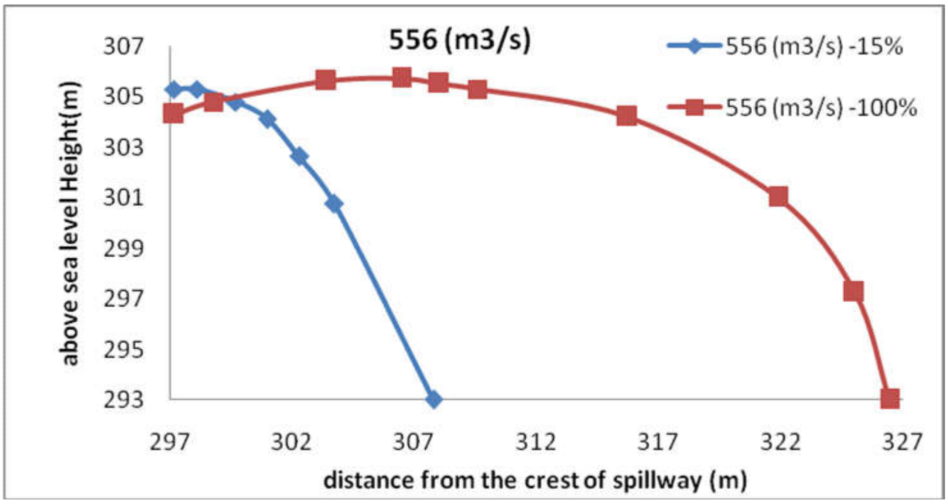

***Figure (6): Speed and cavitations in the opening of 4% in 5 discharges at the beginning of Trajectory***

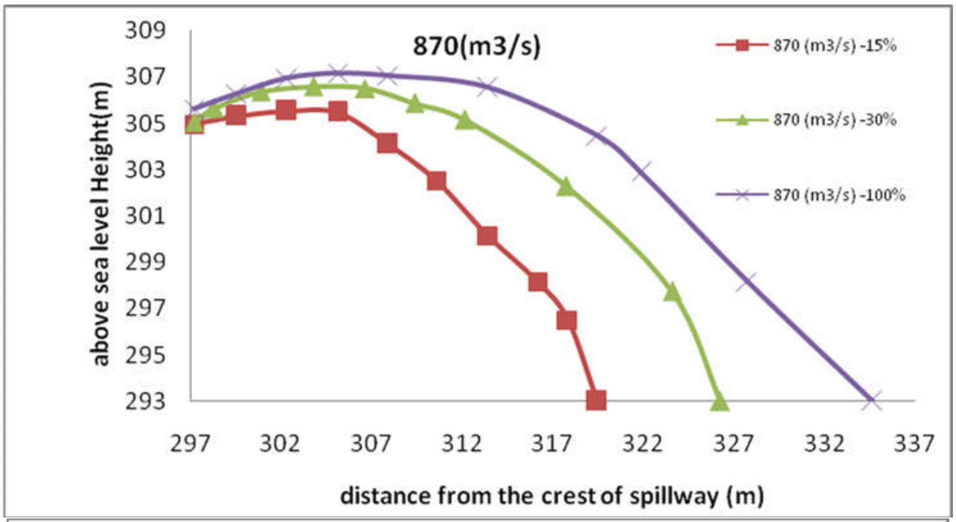
Figure (7) shows the jet trajectory through the flip bucket by passing 5 jet and 4 openings through the flip bucket. Equation (9) shows the percentage of gate opening and its effect on the drop of jet trajectory in comparison with 100% opening. According to Equation (10), through the percentage of gate opening it is possible to obtain the maximum height drop in comparison with 100% of opening. By subtracting the rate of drop from the range and maximum height in each flow it is possible to obtain the range and maximum height according to the rate of desired opening.

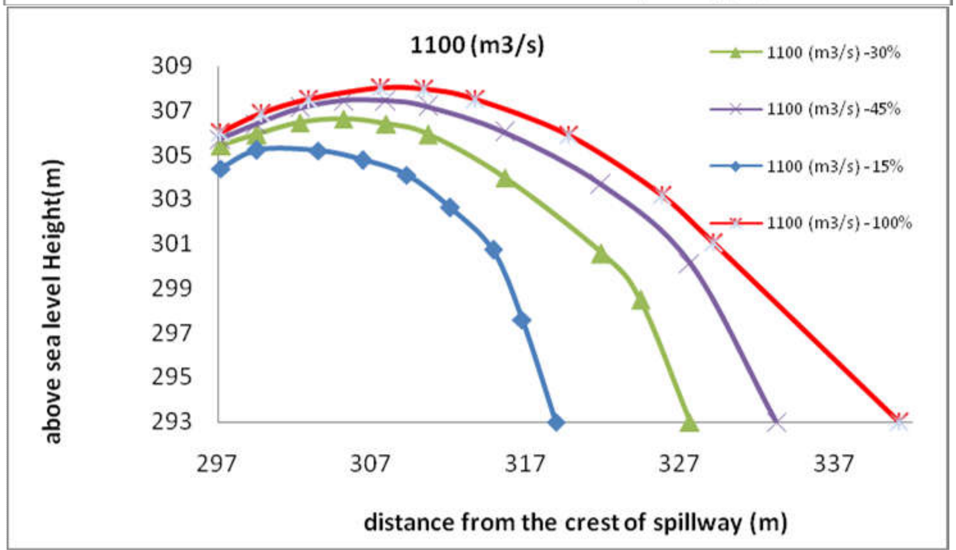
$$R_{opening} = R_{\%100} - [(-0.275\ln(\%opening) - 0.0238)] * R_{\%100} \tag{9}$$

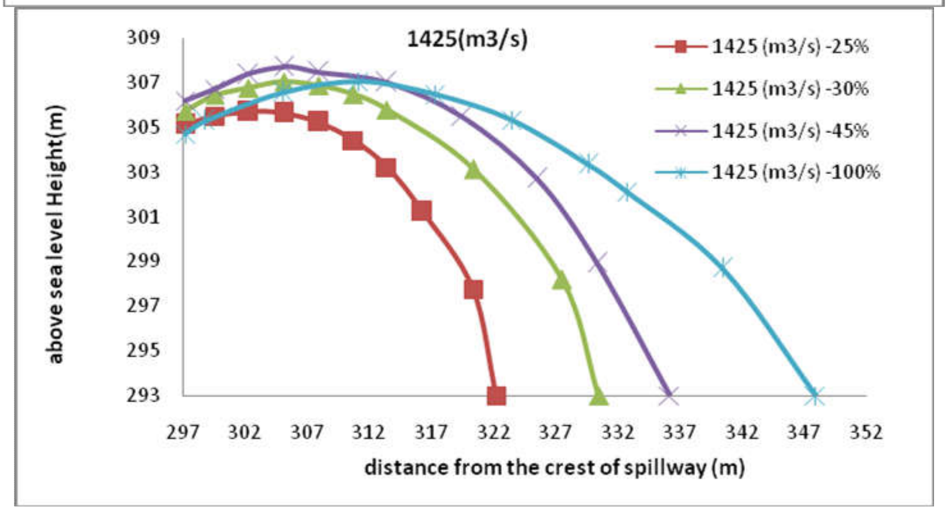
$$H_{opening} = H_{\%100} - (0.0228(\%opening)^{-0.896}) * H_{\%100} \tag{10}$$

In Equations (9, 10) $R_{opening}$ is the rate of opening in percent and $R_{opening}$ is the range of jet trajectory within the rate of gate opening and $H_{opening}$ is the maximum height of jet trajectory at the desired opening. R100% and H100% show the range and the maximum height of jet trajectory for 100% of opening. It should be noted that Equations (9, 10) have been obtained by investigating the jet trajectory in 5 discharges and 4 different openings and examining 200 points on the jet trajectory curve. Furthermore, the conducted validation showed that logarithm equations were highly accurate in flow simulation process.




870(m3/s)
870 (m3/s) -15%
870 (m3/s) -30%
870 (m3/s) -100%
above sea level Height(m)
distance from the crest of spillway (m)
309
307
305
303
301
299
297
295
293
297
302
307
312
317
322
327
332
337


1100 (m3/s)
1100 (m3/s) -30%
1100 (m3/s) -45%
1100 (m3/s) -15%
1100 (m3/s) -100%
above sea level Height(m)
distance from the crest of spillway (m)
309
307
305
303
301
299
297
295
293
297
307
317
327
337


1425(m3/s)
1425 (m3/s) -25%
1425 (m3/s) -30%
1425 (m3/s) -45%
1425 (m3/s) -100%
above sea level Height(m)
distance from the crest of spillway (m)
309
307
305
303
301
299
297
295
293
297
302
307
312
317
322
327
332
337
342
347
352

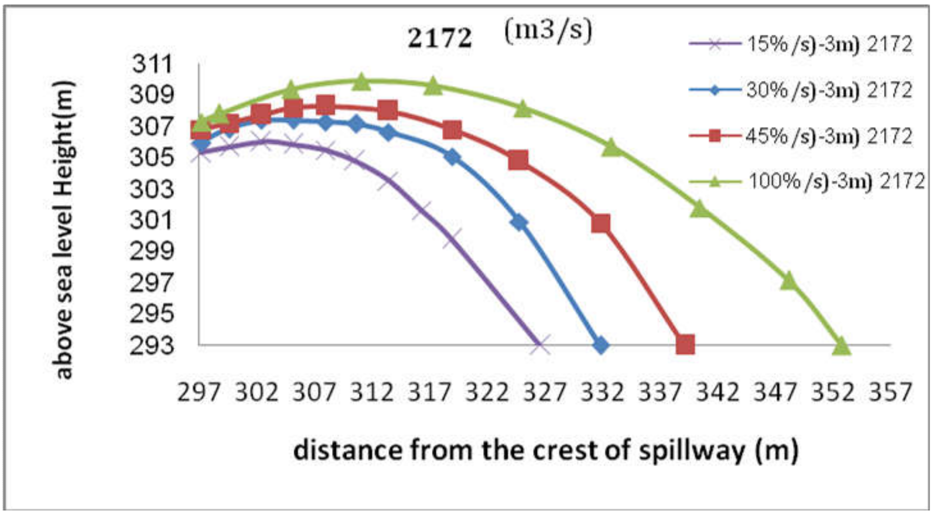



***Figure (7): Jet trajectory curve in 5 discharges and 4 openings***

**CONCLUSION**

This research investigated hydraulic changes of depth, speed, cavitations number, and jet trajectory from the flip bucket, in Balarud Dam spillway influenced by four openings of 15, 30, 45, and 100% and with the help of Flow-3D numerical model. The review of depth changes showed that in the flow of 550 m3/s and 15% opening of the gate, the flow accumulation has occurred due to lower flow discharge than sweeping discharge. Examining speed profiles along the spillway indicates the effect of rooster tail waves on speed fluctuations as well as the effect of cup-shaped lauch on speed drop. The increase of opening has led to the increase of speed and the distance between speed profiles. Examining the spillway body sections showed that the highest cavitation potential belonged to the top of flip bucket and the increase of openings reduced cavitation factor at this point. The numerical results of jet trajectory modeling of flip bucket showed that the error of jet trajectory was about 8.5% and the error of maximum height of jet trajectory was about 7.5% which can be used in prediction of jet trajectory modeling. Moreover, two equations were presented to determine the range and maximum height of jet trajectory based on flow discharge and opening.

**REFERENCES**

1. Samani, H. (2008). Design of Hydraulic structure. Dezab consult company, 495p.
2. Dezab consult company. (2004). Report of first project of ballarood dam. (In Persian)
3. Mehri, M., Fathi moghadam, M., and Ebnejallal, R. 2008. Survey of cavitaion on ballarood dam spillway with physical model. National conference civil. (In Persian).

**CITATION OF THIS ARTICLE**

M Kakeshpour, A Bahadori Birgani, M Johardar, N Naderi, M Bonyadi. Numerical Modeling of the Flow by Investigating the Effects of Opening the Gates on the Hydraulic Flow and Jet Trajectory. Bull. Env. Pharmacol. Life Sci., Vol 5 [5] April 2016: 19-26