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ORIGINAL ARTICLE

Numerical Study of Ski Hydraulic Jump Length of the Spillway

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ABSTRACT
Power dissipation is one of the most important phenomena in hydraulic. For this, various structures such as stilling basins, spillways, torrential streams and cup structures are used. Structure of cup ski is usually used when downstream water is deep. This study considers cup ski jump length for downstream of the dam spillway and uses Flow3d Software to analyze streams hydraulically. In the study, five alternative launchers with a fixed radius of 50 meters and also angles on two left and right channels with (48, 48), (40.74, 40.74), (40.74, 32.30), (34.38, 32.81), (34.38, 28.53) degrees are simulated for 6 Debbies with 4000, 6000, 8000, 10000, 12000 and 16000 cm^3/s, and the results of each stage were selected among previous alternatives and are simulated in the model after changing the structure of next alternative. The results showed that in all Debbies, the maximum length of jump for the right channel relates to the angle with 34.38 degrees and the minimum length of jump relates to the angle with 48 degrees. For the left channel, the maximum length of jump relates to the angle with 28.53 degrees and the minimum length of jump relates to the angle with 48 degrees. In all angles of final bucket, the maximum length of jump is for Debbie with 16000 m^3/s and the minimum length of jump is for Debbie with 4000 m^3/s for both right and left channels.
Keyword*: Cup Launcher, Flow3d Software, Navier-Stokes equations, RNG Turbulence Model*

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INTRODUCTION

During recent years with the increasing trend to construct high dams, the importance of designing an economical and assured power dissipation system has been accelerated in terminals of flood evacuation systems. Using launcher cups along with related submergence basin will have considerable economical and safety advantages in comparison with other power dissipation structures, if suitable geological and topography conditions and also suitable mode of operation are established. There are numerous methods to evacuate flood from either side or over dams. One method is to let the flow to release freely in the air. This goal will be achieved by establishment of free cascade spillways aligned near the dam crest, or torrential spillways ending to launcher cup or with trap doors established on lower alignments of dam.
Using high speed of inflows to the cup, launcher cups in high dams as free launcher jets are able to deviate outflows of spillway somehow that fall down in a safe distance far from spillway and body of dam in submergence basin or river-bed. Cup tranquilizers are used in all short, medium and high kinds of dam at the end of shooting spillways far from main body of dam or output of tunnel and lotus spillways in the lower part of main body of dam, and today, they are paid a great attention due to their economical advantages and higher safety. The hydraulic of cup tranquilizers is based on imposition of cup launch to water flow and formation of two rollers during which, the disturbance and friction caused by interlacement of streams dissipate power. Submerged cup tranquilizers are divided into two simple and grooved types, both types require more trail water depth than hydraulic launch basin for submergence.
Ahadian [1] in a paper considered the effect of temperature to decrease intercourse of submerged jets by means of Flow3d model. He considered various stages of intercourse, length of intercourse, developing regions and developed regions under the terms of temperature difference between jet stream and acceptor stream, and used experimental data for calibration and consideration of accuracy of mathematical model, and finally, simulated temperature concentration distributions for intersecting jet streams and prolapsed curves. While numerically considering the effect of internal friction angle of

sediments on dimensions of scour hole caused by free falling jets by means of Flow3d Software, Amiraslani et al [2] understood that scour hole in sediments with more internal friction angle has less length and width and more depth and downstream of the bump height in comparison with sediments with less internal friction angle. In Denver a city in Colorado State, The Group of Hydraulic Branch Division of Research Engineering and Research Center in 1981 by the person named Clifford A. Pugh considered stream conditions in approaching channels, definition of water-pass through spillways by mixing trap doors, consideration of torrential stream and Philip Bucket and the function of stilling basin in 1:36 test model of spillway of McPhee Dam on Dolores River on south-east of Colorado, USA.

Theory of Study – jet trajectory

Trajected path by the jet depends on primary speed of jet on the edge and deviation angle. To develop geometric descriptive equations for direction, it is possible to use launch theory, assuming that the jet is only affected by gravity, and other parameters are ignored such as air resistance, turbulence, etc. (Figure 1)

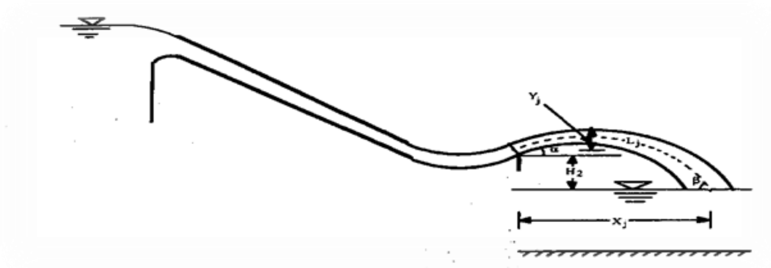

Figure 1: Jet Trajectory and its Direction

Following equation calculates the distance of jet launching and the length of direction:

$$L_j = \frac{\sin\theta_{۲}}{۲\cos^{۲}\theta_{۲}} + \frac{۱}{۲}\ln[\sec\theta_{۲} + \tan\theta_{۲}] - \frac{\sin\theta_{۱}}{۲\cos^{۲}\theta_{۱}} + \frac{۱}{۲}\ln[\sec\theta_{۱} + \tan\theta_{۱}]$$

MATERIALS AND METHODS

Specifications of Dam and Flood Evacuation System:

Gotvand Dam and Power Station in Khoozestan Province is under construction on 25th km of north of Shooshtar City and 12th km of upstream of deviational dam of Gotvand Olia.

- The Type of Dam: Rockfill with clay core
- The Type of Power Station: on-surface. Following table represents qualification of Debbie with various return rates.

Table 1: Qualifications of Debbie with Various Return Rates

Annual return rate	Debbie (m^3/s)	Water level of dam lake (meters from sea level)	Water load on spillway (meters)	Unit Debbie of spillway ($m^3/s/m$)
100	7200	234.5	16.5	120
1000	9050	237	19	150.8
10000	12000	239.8	21.8	200
PMF	17000	244	26	283.33

Establishment of spillway and torrential stream in Gotvand Olia Dam in its Physical Model:

- In hydraulic model, all parts of spillway and torrential stream are made of transparent plexiglass.
- Mahab-Ghods Advisor Company has performed opening gate 4 meters lower than spillway level, and 234-meter balance stabilization of water level of Dam Lake with 1/100 scale in final report of Gotvand Olia Dam.
- In final report of Gotvand Olia Dam, five alternative launchers with a fixed radius of 50 meters and angles on the left and right channels (48 & 48), (40.74 & 40.74), (32.30 & 40.74), (32.81 &

34.38) and (28.53 & 34.38) degrees for 6 Debbies 4000, 6000, 8000, 10000, 12000 and 16000 m³/s are performed are performed in a phasic style.

Figure 2: Physical Model

Mathematical Model

Mathematical model is a model being formed based on governing relationships on a phenomenon; so, only the group of hydraulic phenomena can be changed to mathematical equations which first of all, mathematical relations ruling the phenomenon are explored and second of all, there is an acceptable way and suitable tool to solve these equations. Flow3d Software resolves equations governing the motion of fluid by means of approximate volume limit. The environment of stream is broken down to rectangular-cell meshes, for which there are mean values of related quantities. Namely, all variables are calculated at the center of cell instead of the speed which is calculated at the center of cell sides. This software uses two numerical techniques for geometric simulation:

Equations of fluid motion include equations of mass conservation, momentum and energy conservation which are called Navier-Stokes Equations in their differential form. Followings are Equations governing 3D stream in this software:

$$V_F \frac{\partial \rho}{\partial_t} + \frac{\partial}{\partial x}(\rho u A_x) + R\frac{\partial}{\partial y}(\rho v A_y) + \frac{\partial}{\partial z}(\rho w A_z) + \xi \frac{\rho u A_x}{x} = R_{DIF} + R_{SOR}$$

$$\frac{\partial u}{\partial t} + \frac{1}{V_F}\left\{uA_x \frac{\partial u}{\partial x} + vA_y R\frac{\partial u}{\partial y} + wA_z \frac{\partial u}{\partial z}\right\} - \xi \frac{A_y v^2}{xV_F} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + G_x + f_x - b_x - \frac{R_{SOR}}{\rho V_F}(u - u_w - \delta u_s)$$

$$\frac{\partial v}{\partial t} + \frac{1}{V_F}\left\{uA_x \frac{\partial v}{\partial x} + vA_y R\frac{\partial v}{\partial y} + wA_z \frac{\partial v}{\partial z}\right\} + \xi \frac{A_y uv}{xV_F} = -\frac{1}{\rho}\left[R\frac{\partial p}{\partial y}\right] + G_y + f_y - b_y - \frac{R_{SOR}}{\rho V_F}(v - v_w - \delta v_s)$$

$$\frac{\partial w}{\partial t} + \frac{1}{V_F}\left\{uA_x \frac{\partial w}{\partial x} + vA_y R\frac{\partial w}{\partial y} + wA_z \frac{\partial w}{\partial z}\right\} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + G_z + f_z - b_z - \frac{R_{SOR}}{\rho V_F}(w - w_w - \delta w_s)$$

$$V_f \frac{\partial F}{\partial t} + \nabla.(AUF) = 0$$

In recent study, cup ski jump length downstream of the dam spillway was considered and five alternative launchers with a fixed radius of 50 meters and with angles on both left and right channel with (48, 48), (40.74, 40.74), (40.74, 32.30), (34.38, 32.81), (34.38, 28.53) degrees are simulated by Flow3d Software for 6 Debbies of 4000, 6000, 8000, 10000, 12000 and 16000 cm³/s.

According to provided geometry in Auto Cad Software and introduction of boundary conditions consistent with Debbies to design physical models in Flow3d Software, the stream passing over launcher cup in physical model is simulated in this stage and achieved results are compared with those achieved by offered equations. For this purpose, at first the software is calibrated by one of the Debbies and then, it is verified by the other Debbies. To do this, final report of physical model of Gotvand Olia Dam is used. (Figure 3)

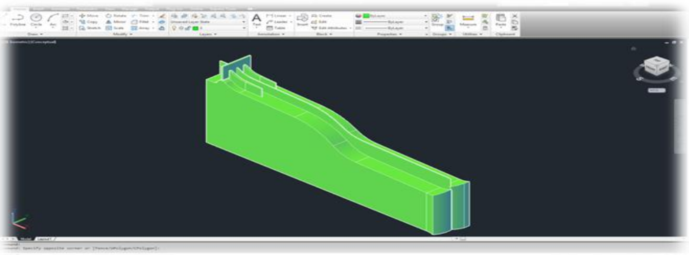

Figure 3: Simulated Mathematical Model

RESULTS

Output results are as 2D and 3D views of structure and its meshes. The results are transferred from the software, introduced in this study, to Excel to draw necessary charts.

Two items are considered to examine the effect of bucket angle of ski cup on the jump length:

1- Consideration of the effect of bucket angle on jump length for fixed Debbie

2- Consideration of the effect of stream intensity on jump length for fixed bucket angle

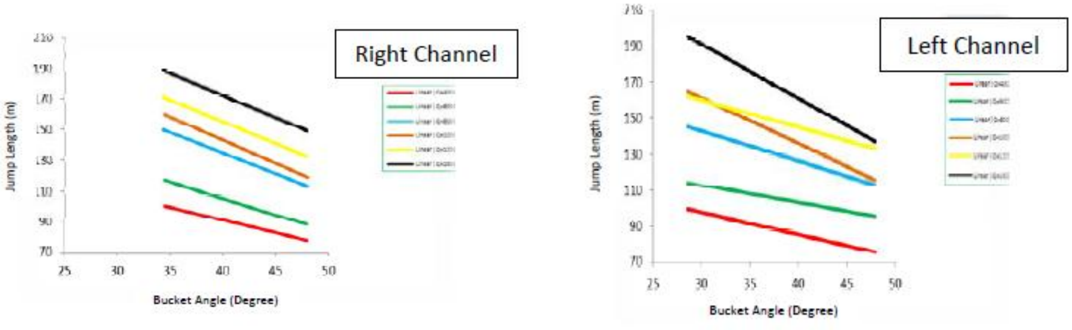

Figure 4: Changes of jump length according to final bucket angle on two left and right channels

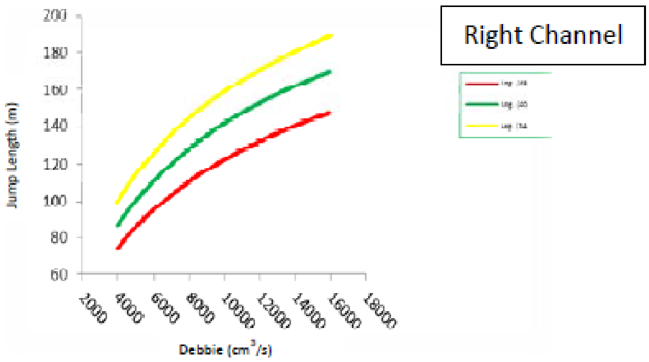

Figure 5: Changes of length toward Debbie

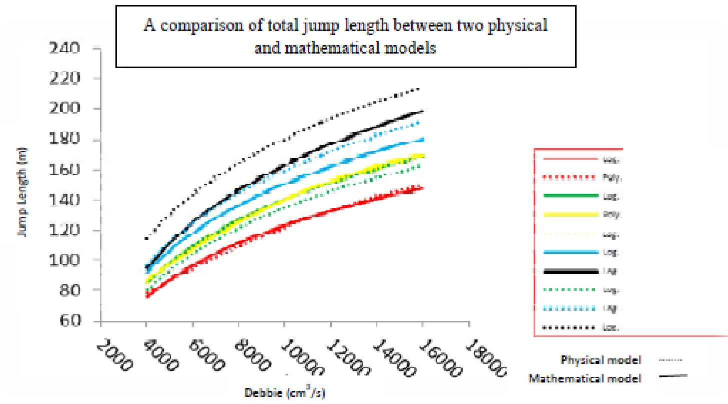

Figure 6: A comparison of total jump length between two physical and mathematical models

As an example, 3D presentation of stream is offered in two various angles:

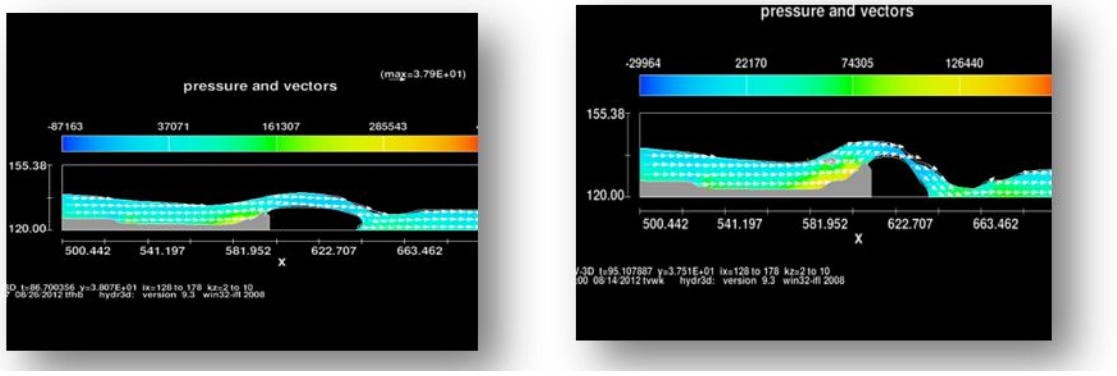

Figure 7: 3D Presentation of Stream

DISCUSSION

1- According to results achieved by physical and mathematical models, it is obvious that in all Debbies the most jump length is related to 34.38° angle and the least jump length is related to 48° angle among other angles on the right channel.

2- According to results achieved by physical and mathematical models, it is obvious that in all Debbies the most jump length is related to 28.53° angle and the least jump length is related to 48° angle among other angles on the left channel.

3- The results show that in all final bucket angles, the most jump length is related to 16000 m^3/s Debbie and the least jump length is related to 4000 m^3/s Debbie on both right and left channels.

REFERENCES

1. Ahadian, J.; Musavi Jahromi, H. (2009). A Consideration on Effective Factors on Development of Stream of Submerged Jets in Static Receiver Water Resources, Journal of Water and Soil (Agricultural Science and Technology), Volume 23, No: 4
2. Amiraslani, Sh.; Pirestani, M.; Shalehi Neishaboori, A. (2008). Numerical Consideration of the Effect of Internal Friction Angle of Sediments on Dimensions of Scour Hole Caused by Free Falling Jets, Second National Conference of Dams and Hydraulic Power Stations

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