Physical hydraulic model study of the Howell-Bunger valve at the Upper Mamquam powerhouse by-pass outlet

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Introduction

During the test opening of the fixed cone dispersion valve at the Upper Mamquam powerhouse by-pass outlet the back splash from the stationary hood into the valve chamber occurred. The physical hydraulic model study was conducted with the objective to find an acceptable modification of the existing valve and discharge hood combination. The main issue was to suppress the excessive back splash and to contain it to the amount that could be drained.

The model simulation of the current prototype situation proved the existing problems. The back splash occurred even at smallest valve openings and intensified when the opening was enlarged. Since the back splash seemed to result from inappropriate water jet reflection in the hood, the goal of the following variants was to limit this rebound to the conical part of the hood. Firstly, the edge between the conical and the cylindrical part was moved locally downstream and the incline of the conical part of the hood was reduced. The observations proved no significant improvement of hydraulic conditions. At that point the further reshaping of the hood was not approved; therefore we proceeded with changing the distance between the valve and the originally designed hood. These measures proved to be inappropriate, irrespective of the valve displacement direction. Consequently the modifications of the hood by the additional parts were taken into consideration. These supplements were placed on the upstream part of the hood, extending it into the valve chamber. During the course of the research we focused on certain additional parts that had previously been assembled at the prototype, but have not contributed to any improvement since then. The combination of the appropriate valve displacement in the upstream direction and some further modifications of the hood prolongation represented an adequate solution that was confirmed by the back splash.

It turned out, however, that the proposed move of the valve would cause welding difficulties; therefore a different solution had to be found. A combination of previously researched measures was suggested.

1. Background

The Upper Mamquam Hydro Plant is a run-of-river hydro project, located 10 kilometers east of Squamish in British Columbia, Canada. The construction started in November 2003 and was completed in July 2005. The water from the Mamquam River is diverted through a penstock into two Pelton turbines, located in the powerhouse downstream. The water turns the turbines, generating 25 MW of power, and is returned to the river directly below the powerhouse. The distance from the water intake to the powerhouse is 1.7 km. At full flow, 27 m^3/second pass through the turbines. The unique features of the plant include a 145 m tunnel, allowing the buried steel penstock to pass through a rock wall and a bypass valve for the uninterrupted river flow. As the application requires restriction of the discharge spray (to protect the nearby electrical equipment from the overspray moisture or to prevent icing on the nearby structures), a discharge hood was employed. During the test opening of the valve the back splash into the valve chamber occurred.

2. Physical hydraulic model

The research was carried out in the laboratory of the Institute for Hydraulic Research. The 1:10 scale model of the valve was delivered by the Upper Mamquam's T/G supplier, the company Litostroj E.I. It was made of steel and fixed to the piping, while the corresponding discharge hood was made of transparent plastic and mounted to a moveable carriage, placed over an open reservoir. This installation enabled changing the distance between the hood and the valve and to visualize the flow conditions in the hood. The valve model was open to atmosphere, although the prototype valve chamber was an enclosure with 1.4 m^2 opening. The supplier of the valve estimated that this opening would prevent the air supply problems in the prototype.

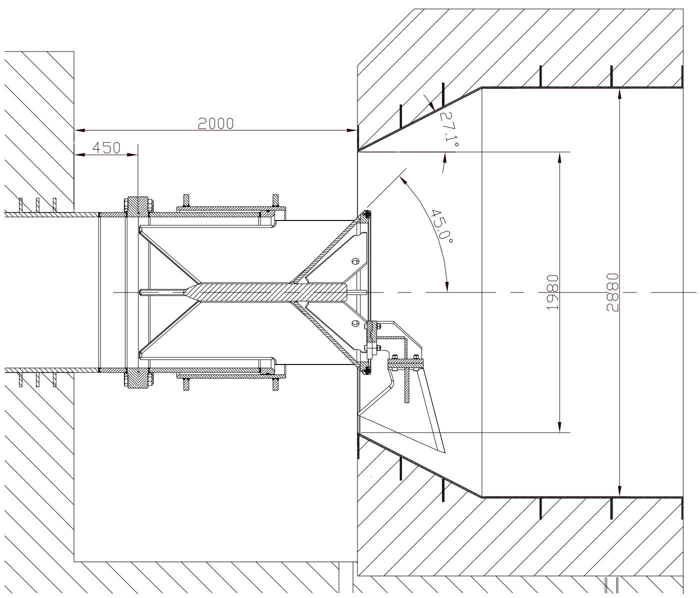
The water for the model was continuously pumped to the top of 13 m high cylindrical reservoir where it spilled into the piping and flowed gravitationally through the regulating valve and an electromagnetic flow meter. The water jet, exiting the hood, fell freely to the underground reservoir of the laboratory.

The mean piezometric pressure was measured with the precision pressure gauge, just upstream of the flange connecting the valve with the piping (i.e. at the upstream wall of the valve chamber).
The evaluation of the back splash dictated the construction of special container which intercepted the back splash and drained it to the measuring volume.

As the prototype valve chamber allowed an adequate air supply (or could be modified to do so, in case the problems of that kind occurred), the research of that issue was limited to observations of the water jet exiting the hood. The significant differences between the water jets of various configurations could indicate the problems with the air supply. However, no such differences were noted during the observations.

Fig.1: Valve discharge at 15% opening of the valve.

Fig.2: Back splash in the valve chamber.



Type: Fixed cone
Quantity: one (1) set
Nominal diameter: 1067 mm
Design pressure: 180 m.w.c.
Gross head on the valve: 120 m.w.c.
Net head on maximal plant flow: 109 m.w.c.
Discharge at normal max. head: 27,0 m^3/s
Position of valve axis: Horizontal
Type of connection: Flange type
Type of actuator: Hydraulic servomotors
Operating time: 40 – 60 s

Fig.3: Longitudinal section of the prototype Howell-Bunger valve (in mm) and its main characteristics (right).

3. Results of model studies

3.1 Simulation of the prototype situation

The model simulation of the current prototype situation proved the existing problems of the back splash. The back splash occurred even at smallest valve openings and intensified with the increase of the opening. For the openings, exceeding s = 75 %, it was observed that the back splash increase somewhat stabilized at certain level, while the spraying into the valve chamber increased with further openings. It was reported that the back splash on the prototype appeared first at the valve opening s = 10 %, while on the model it started as soon as at s = 5 % opening. With the project distance between the valve and the discharge hood, and for the openings smaller than s = 30 %, the water jet, exiting the valve, hit the cylindrical part of the hood. The further opening of the valve caused that the location of this collision moved closer to the valve. No vibrations were noted, irrespective of the valve opening.

3.2 Preliminary modification of the discharge hood

Since the back splash seemed to result due to the inappropriate water jet reflection from the hood, the goal of the following variants was to achieve that this collision would take place in the conical part of the hood. Keeping this in mind, an additional piece was inserted into the upper part of the hood. With this installation the edge between the conical and the cylindrical part of the project hood was moved locally for 25 cm downstream *(dimensions in this article represent dimensions in nature),* making the oblique part of the hood longer and more gradual. The additional part embraced only 1/3 of the conical region of initial hood.

The observations demonstrated no significant improvement of conditions. It appeared that the employment of such a piece (that would embrace the entire circumference) could even cause aggravation, but such modification was not tested to a greater degree. Furthermore, changing the shape of the prototype discharge hood would be quite demanding. Based on these conclusions such arrangements were refuted as insufficient.

3.3 Changing the distance between the valve and the originally designed hood

During the course of the research it became evident that the optimal flow conditions at various valve openings occurred at configurations with different distances between the valve and the hood. Therefore the aim of this study was to determine such a distance that would enable the best possible conditions for the whole range of the valve openings. We focused on the openings from 5 % to 80 %, the latter being the biggest valve opening during normal prototype operation.

At first the moving of the valve into the hood seemed the easiest way to contain the back splash. However, reducing the distance between the valve and the hood proved inadequate. We observed cases of valve being moved for 10, 20, 40 and 70 cm (measured for the nature) in the downstream direction from the initial position. During the course of the study it became evident that the back splash is significant and that conditions practically did not vary with the downstream displacement of the valve. Therefore these measures were unacceptable.

Fig. 4: Valve moved 10 cm downstream, s = 20 %.

Fig. 5: Valve moved downstream, s = 80 %.

Moving the valve in the opposite direction, that is, out of the hood, gave similar results. The observation of the cases with large valve openings proved that the conditions were even worse if the distance between the valve and the hood was too great.

3.4 Extensions of the discharge hood

Changing the distance between the valve and the originally designed hood proved to be inappropriate, irrespective of the valve displacement direction. Therefore, in order to modify the discharge hood, the additional parts were taken into consideration. These supplements were placed on the upstream part of the hood, extending it into the valve chamber.

The tapered part of the hood being lengthened in such a way, the positive effect on the flow condition was achieved only if the valve was moved upstream, closer to the inlet of the hood's new conical part. This caused the jet to hit the tapered part of the hood, which resulted in the reduced back splash.

3.4.1 Variant A

Firstly, the tapered part of the hood was gradually lengthened with smaller parts until the construction reached 30 cm into the valve chamber. The angle of the extension was identical to the one in the conical region of the hood. Due to the fact that this variant indicated satisfactory results and the research of the Litostroj's additional piece was in progress, we focused on the latter.

3.4.2 Variant B – Litostroj's additional piece (LT 54)

Before the construction of the discussed hydraulic model Litostroj attempted to solve the back splash problem by placing an additional part to the inlet of the original discharge hood, extending it for 54 cm (thus mark LT 54) into the valve chamber under 12° inclination. However, this arrangement proved insufficient. The model study of this configuration showed that the back splash for the case of s = 10 % opening amounted to 408 l/s.
As the movement of the valve in the upstream direction promised better results (Variant A), we proceeded with the shifting the valve away from the hood. The required valve displacements for substantial improvement of flow conditions (optimal positions) ranged from 10 cm for s = 80 %, up to 24 cm for s = 5 %.

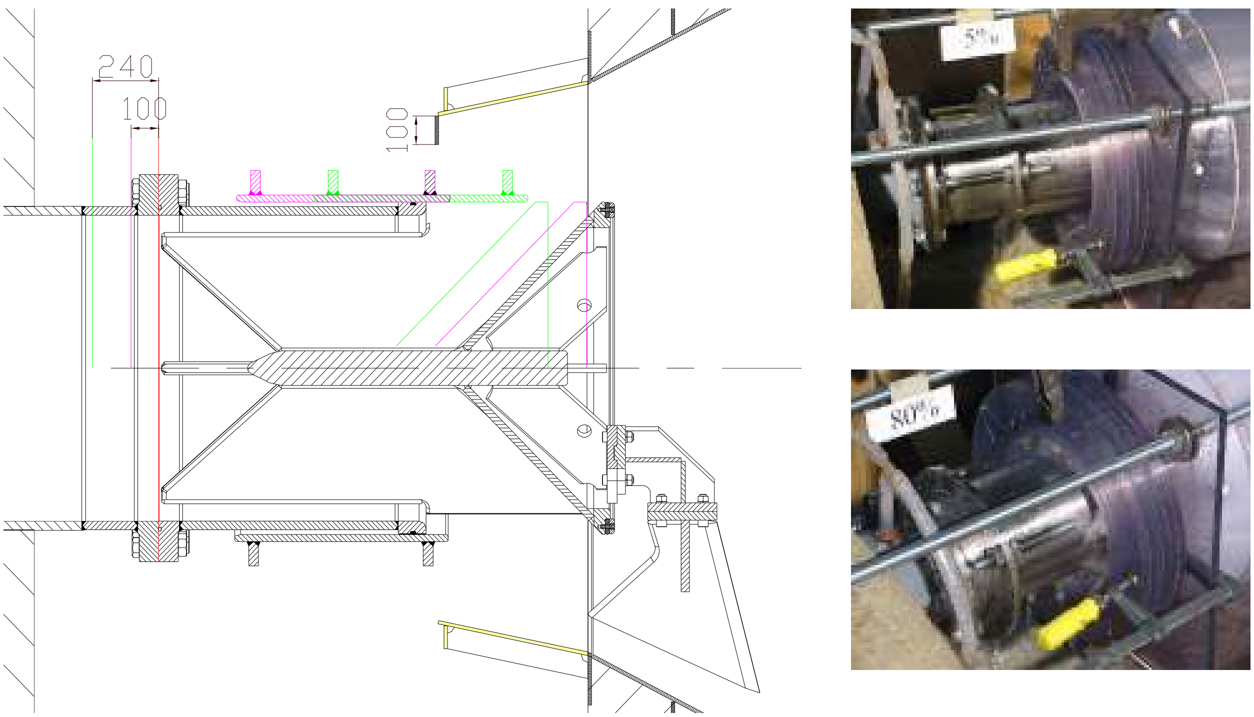


Fig.6: The lower half of the drawing shows the employment of the Litostroj's additional piece (LT 54) only, while the upper half shows the changed geometry due to the additional ring on LT 54; optimal position of the valve for s = 5 % opening is in green (photo top right), the optimal displacement of the valve for s = 80 % opening is in magenta (photo below).

Various combinations with LT 54 employed were observed, and finally the 24 cm upstream move of the valve was suggested as the first acceptable solution. This decision was based mainly on the following observations:

1) The combinations with a short move and a small opening could lead to an air supply problem. For example: at 10 cm move with s = 5 % opening distinctive a noise appeared, indicating potential air supply issue.
2) The conditions at 24 cm move seemed optimal or very good for most of the valve openings.
3) The measured back splash at 24 cm move and 80 % opening amounted to quite acceptable (and drainable) 51, 4 l/s, while other openings caused less back splash.

Moving the prototype valve in the upstream direction could represent considerable difficulties. To minimize the required move of the valve, the back splash at 20 cm (instead of 24 cm) valve displacement was measured as well. It turned out that this variant gave even better results in the view of the back splash quantity (42,2 l/s at s = 80 %), but the spraying into the chamber seemed more distinctive than in the case of 24 cm move. Subsequent tests showed that this splashing and spraying could be contained within the additional ring, placed on the front of LT 54 piece. This ring was placed perpendicularly to the valve axis and it reduced the hood opening diameter for additional 20 cm. The measured back splash then amounted to only 10, 5 l/s at s = 80 %.

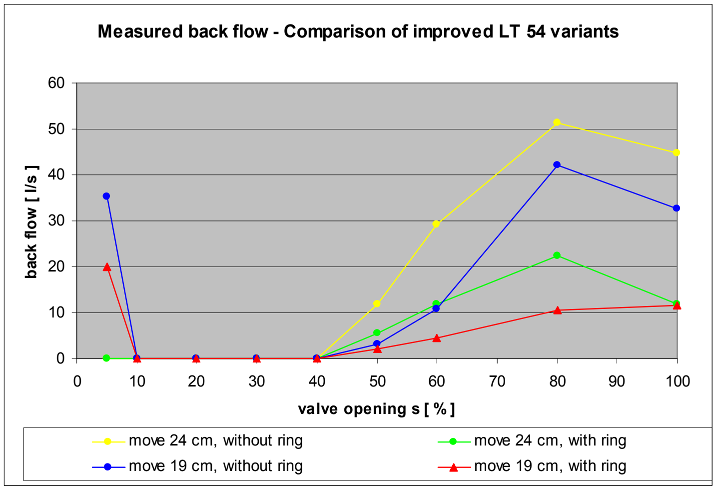


Fig.7: Some results of the back splash measurements show significant influence of the additional ring.

In this way the following combination was suggested: LT 54, the additional ring and the valve moved 20 cm upstream.

3.5 Final modifications

Even shorter, 20 cm long move of the valve would present difficulties in preparation and the assurance of the quality field weld, therefore a new solution was suggested. In an attempt to achieve the positive results without moving the valve, an altered conical part of the hood was employed (Fig.8), while the valve remained in original position and the hood was equipped with the previously proposed supplements (LT 54 and ring).

The observations indicated that the flow conditions were indeed identical to those of previously suggested measures, making this variant an acceptable one.

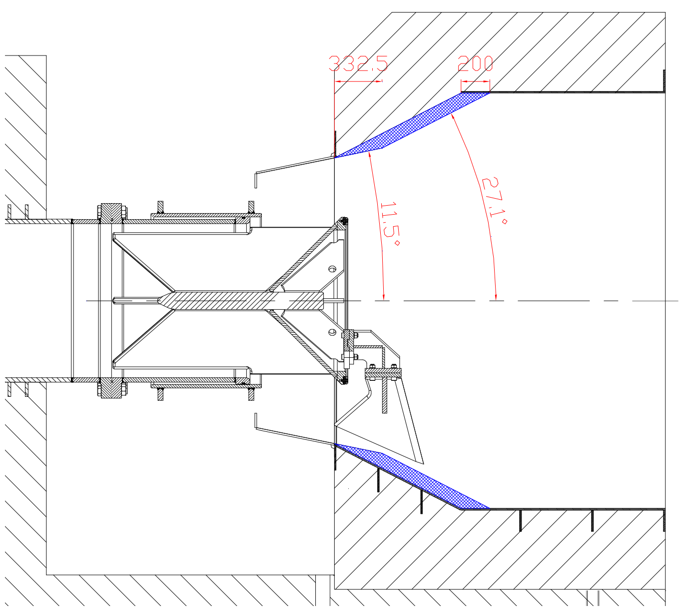


Fig.8: The longitudinal section of the final solution (in mm): The combination of LT 54, ring and hood modification.

References

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Primož Rodič graduated in Civil Engineering from the University of Ljubljana, Slovenia, in 1993. Since then he has been employed at the Institute for Hydraulic Research as a researcher. His main researches were the hydraulic model research and the mass oscillation study of the HPP Plave II and HPP Doblar II surge tanks on the river Soča. Furthermore, he elaborates studies on the environmental field (e.g. temperature regime on the river Sava in Slovenia), and carries out field and laboratory measurements. He is also a post-graduate student at the Chair of Hydrology and Hydraulic Engineering.

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