TRANSIENT MODEL TEST OF SURGE TANK REISSECK 2

W. Richter[1], H. Knoblauch[1],G. Zenz[1], M. Larcher[2]

[1]Institute of Hydraulic Engineering and Water Resources Management TU Graz, Austria, Stremayrgasse 10 /2

[2]VERBUND Hydro Power AG, Am Hof 6a, 1010 Wien, Austria

E-mail: wolfgang.richter@tugraz.at, helmut.knoblauc@tugraz.at, Markus.Larcher@verbund.com

Abstract

To design and to verify the hydraulic functionality of the surge tank Burgstall, investigations and model tests were carried out at the Institute of Hydraulic Engineering, TU Graz. An asymmetric orifice throttle was checked in a model test scaled by Reynolds similitude law to determine the loss coefficients. The complete surge tank was constructed in scale of 1 / 25 in acrylic glass to visualize and verify the functionality of the hydraulic behavior.

Keywords: hydraulic model test, surge tank

Introduction

The pump storage plant Reisseck 2 is constructed between the two existing hydraulic systems of HPP Malta main stage and HPP Reisseck. At the tail water side of Reisseck 2 the new surge tank Burgstall is providing the hydraulic compensation for the shifting cases in the power plants Reisseck 2 and Malta main stage (Freitag et al. 2011).

The surge tank is designed for a combination of extreme load cases for the two hydraulic systems. It is situated next to the existing surge tank Hattelberg which is equipped with a reverse flow throttle including a significant asymmetric loss coefficient. The aim of the surge tank is to provide the possibility of secure operation for open load cases of the power plant at minimum construction effort. The surge tank Burgstall is designed as a chamber surge tank of differential type with an asymmetric orifice throttle.
To prevent the pressure tunnel from critical negative pressure an air vent shaft is installed to aerate the lower chamber. This shaft is not conducted as usually to the upper chamber, but to the level of maximum storage in the reservoir. The hydraulic system was calculated in 1D-numerical approach regarding also secondary effects as surge waves in the chambers and the separation of the water column in the shaft. A valve controlled model test was performed in the laboratory of the Institute of Hydraulic Engineering and Water Resources Management to check the transient flow situations in all parts of the surge tank. The aim is to check the functionality of the surge tank also regarding two-phase phenomenon.

Hydraulic system

The surge tank Burgstall is situated at the tail water side of the power cavern of Reisseck 2 which is connected at the upper water side of Malta main stage HPP. A combination of extreme load cases considering generating mode as well as pumping mode at both power houses at flow situations for resonance shifting. For example the maximum upsurge case is giving at generating mode with all turbines for Reisseck 2 and load rejection of all turbines in Malta main stage. Hydraulic optimizations in terms of 1D-numerical calculations were carried out to design the surge tank Burgstall linked in the hydraulic systems and hydraulically connected to the surge tank Hattelberg. The surge tank Hattelberg is equipped with a reverse flow throttle with a high asymmetric loss ratio (Steyrer 1999).

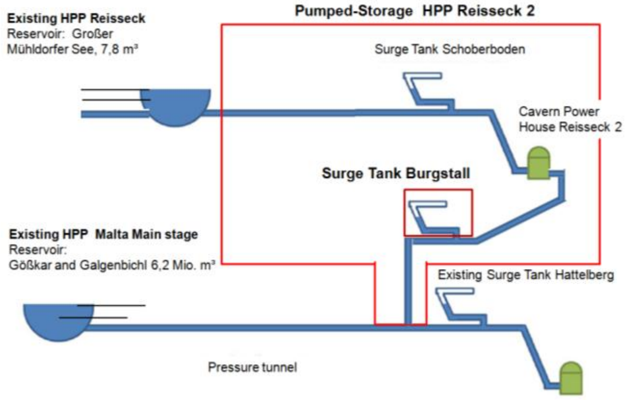

Figure 1: Hydraulic system of Reisseck 2 and surge tank Burgstall (systematical)

To provide stable hydraulic conditions during generating mode and to keep an equivalent surface in the main shafts of both surge tanks, a shaft enlargement at the surge tank Burgstall in combination with a orifice throttle are foreseen.

Surge tank Burgstall

In hydraulic connection to the power cavern the surge tank Burgstall in dimensioned to ensure enough volume to avoid overflow in the upper chamber and complete draining in lower chamber. The throttling concept is adjusted to the existing hydraulic system and lowers the volume demand of the surge tank as well as ensuring stable and smooth operations for the machines. The design is derived by hydraulic, geological and geometric demands. The curved upper chamber in horseshoe shape connects the main shaft to the aeration building at the end of the tunnel that is directly at the surface of the mountain at an altitude of about 1750 m.a.s.

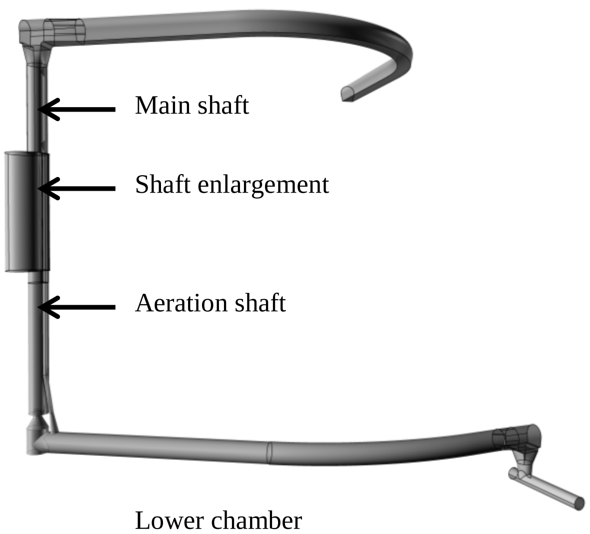

Figure 2: Surge tank Burgstall geometry

Asymmetric orifice throttle

Regarding an optimal hydraulic loss coefficient ratio between upsurge and downsurge direction the orifice throttle is designed. A high ratio is decreasing the volume demand especially for the lower chamber and has positive effects to the controllability of the hydraulic system (Seeber 1970). First the upsurge loss coefficient is determined in consideration of the tolerable pressure in the conduit system. In case of the Burgstall surge tank the loss coefficient is comparable to the loss coefficient in the adjacent surge tank Hattelberg to ensure an equal upsurge behavior. The downsurge loss is then given by the ratio factor. To maximize the ratio factor for an asymmetric orifice throttle the up flow resistance is built by a smooth contraction at the smallest diameter versus an increased contraction for down flow at the same section by combining with hydraulic characteristics that only act at opposite flow direction. Figure 3 show the model throttle with a section cut through center plane. The loss coefficient for down flow direction is increased by the orifice that reaches into the shaft.

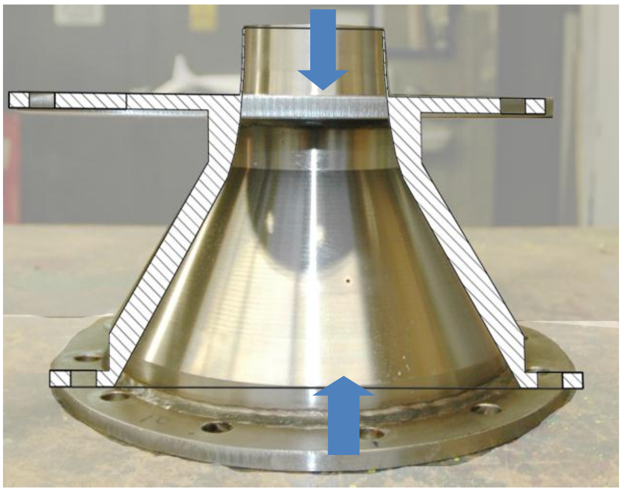

Figure 3: Asymmetric Throttle stainless steel, section cut and full view

Investigations

For verification of the functionality of the surge tank in first step 3D-numerical simulations where carried out to optimize the loss coefficient for different positions of the asymmetric orifice throttles. For determination of the loss coefficient in upsurge and downsurge direction a model test regarding Reynolds similitude law was carried out with the scale factor 1 to 25. Therefore parts of the lower chamber and the shaft where constructed in stainless steel and the measurements where undertaken.

Asymmetric throttle model test

Regarding previous 3D-numerical investigations the position of the throttle is situated at the bottom of the main shaft. The aeration shaft is connected to the crown of the lower chamber at a short distance to the throttle. The lower part of the aeration shaft has a conical widening. The aeration shaft is guided within a block out of the main shaft. For the model test by hydraulic scaling with the Reynolds similitude laws following variations were investigated:

- Throttle in position on right side
- Throttle in position on left side
- With flow in the aeration shaft
- Without flow in the aeration shaft
- Edge of throttle with sharp 90 degrees shape
- Edge of throttle with 45 degree chamfer

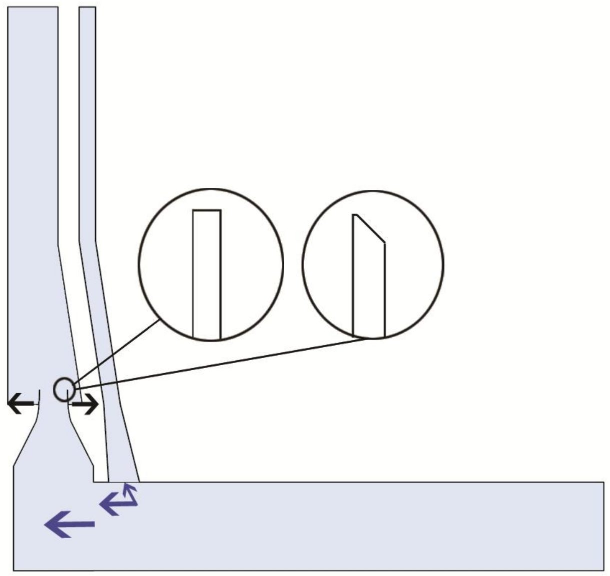

Figure 4: Variations for throttle optimization

The investigations have shown a negligible difference to the loss factor by considering or not considering the flow through the aeration shaft. Due to the aeration shaft that is leaded in the main shaft huge dynamic forces along the concrete and steel lining above the throttle were considered. Therefore two positions of the throttle were investigated but no significant influence to the loss coefficient was found.

A substantial influence to the down surge loss factor was found by a modification of the throttle edge. By chamfering the edge at an angle of 45 degrees on the outside an increase of the loss factor of about 15 per cent is possible.

The aim is to find a maximum contraction of the flow section at down flow. Following streamlines from the main shaft at down flow great parts of the water have to find the exit through the orifice by the loop way outside of the throttle wall. A sharp bending of the streamlines forces a contraction in combination with the high water velocity at the center of the orifice. Adding the chamfer is comparable with an even thinner steel wall of the mouth piece. Due to static and dynamic forces a minimum of steel is necessary.

Surge tank model test

The surge tank and its damping function take action at shifting operations due to valves at the power cavern. All load cases regarding oscillations in the surge tank follow transient flow situations. The main influence to the mass oscillation is given by the mass of the water in the pressure tunnel.

By reasons of limited space in the laboratory it is not possible to model the pressure tunnel and its acting mass of water. The surge tank is cut out of the conduit system. The pressure tunnel and the connected reservoir as well as the turbines and pumps are represented by controlled valves (Figure 7). To increase the suction head at the outflow of the model a pump is situated. The valves operate with pressured air and are controlled by magnetic flow meters. The model test discharge information is compared in real time with the input parameters from the 1D numerical calculation. So the model test is governed by the input of the 1D numeric that also contains the surge tank as a model. By running the physical model test with the boundary conditions of the simulations a testing and improvement of modeling a surge tank in terms of 1D numerical simulations could be achieved.

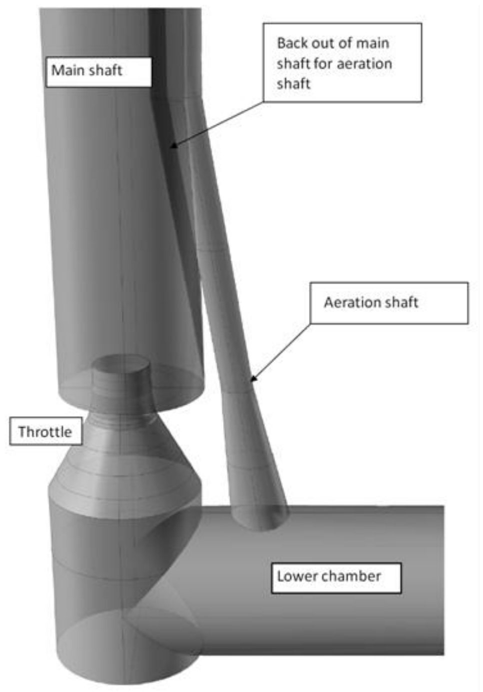

Figure 5: Position of asymmetric throttle

For measuring purpose the surge tank was equipped with 14 measuring points. The points were connected with water filled measuring pipes and pressure sensors at a well-defined level. The measuring points were situated as followed:

- 5 Sensors in the lower chamber
- 1 Sensor in the aeration shaft
- 3 Sensors in the main shaft
- 5 Sensors in the upper chamber

The evaluation of the measurements at the same time of all points was post processed to an animation of the transient flow process of the surge tank.

In Figure 6 the evaluation of the pressure measurement in the lower chamber is visualized. The continuous lines show the results from 1D-numerical simulations compared with the results from the model test (slashed line). The measuring of the pressure n the lower chamber is representing the pressure as it is acting on the conduit system. So the pressure head of the aeration shaft is the acting head on the conduit system. Due to the high loss coefficient in down flow direction the main shaft is hydraulically disconnected from the conduit system and only acts as water reservoir in this case.

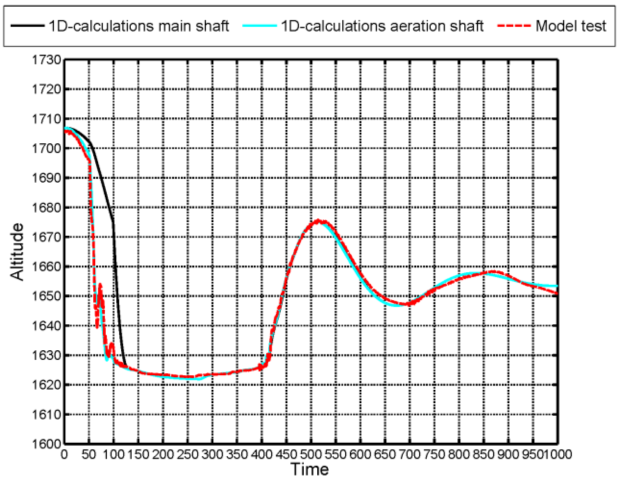

Figure 6: Comparison 1D numerical calculations to model test measurements

It could be found a very good agreement by the comparison of the physical model test with 1D-numerical simulations.

Furthermore the model test was used to compare and verify the numerical model for the combined evaluation of pipe flow and free surface flow in a surge tank.

It was possible to visualize the waterfall at the overflow of the upper chamber in terms of the acting head on the conduit system.

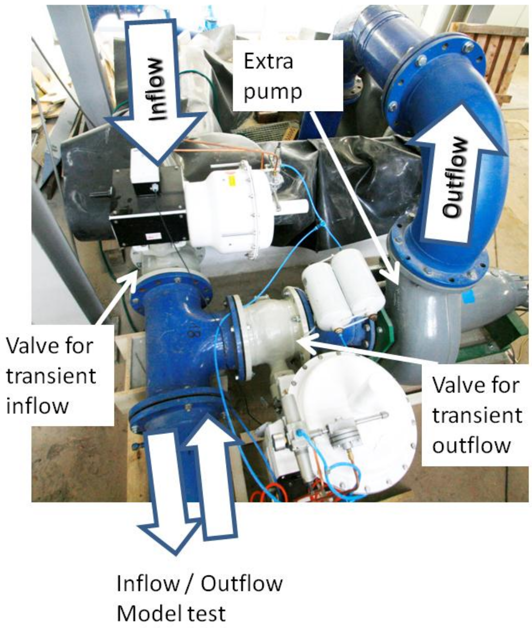

Figure 7: Inflow and outflow valves for transient discharge

Figure 8: Asymmetric Throttle at end of lower chamber with scaled model figure

Figure 8 shows the comparison of a model size person to the acrylic glass model. To avoid high under pressure in the pressure tunnel below the lower chamber during the downsurge process an aeration shaft is situated. This aerates the lower chamber and avoids a separation of the water column in the pressure tunnel. This column separation could have dangerous pressure effects on the pipe.

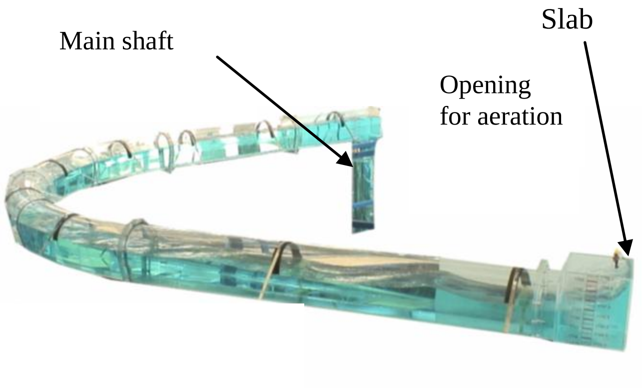

Figure 9: Upper chamber at maximum wave at aeration facility

Figure 9 shows the filling of the horse shoe shape upper chamber at the time of the highest surge wave breaking at the aeration building at the end of the tunnel. It was verified that the breaking wave does not overflow the construction. This was achieved by a covering slab.

Due to a head of about 7 meters water column in the model test the acrylic glass material needed to be reinforced and stiffened at several points. Attention need to be given on stress peaks located where the circle shape sections have a transition to vertical walls attention.

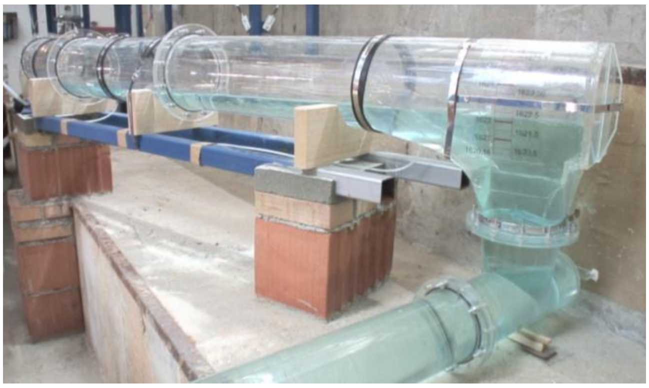

Figure 10: Lower chamber at minimum water level

Figure 10 shows the connection of the lower chamber to the pressure pipe. A slight hydraulic transition is important for emptying process to avoid intake vortices.

Conclusions

The transient model test of the surge tank Burgstall could confirm its hydraulic functionality. According the controlling load cases for the chamber dimensioning it was shown. No overflow occurs due to filling and breaking of the highest wave in the upper chamber. Also the minimum level does not fall below the calculated one.

The water levels measured in the physical mode test match in a very good way to the levels calculated by terms of 1D numerical simulation. The model test could prove the functionality of the aeration shaft that does reach the level of a short distance higher than the capacity level. The overflow at the edge of the upper chamber could be improved by applications adapted by the physical model test to lead the waterfall due to column separation to the center of the main shaft.

By adding a chamfer at the edge of the throttle an increase of about 15 percent to down flow loss factor was achievable.

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