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Characterisation of hydraulic behavior of surge tanks orifices

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1. Introduction

Hydroelectric plants have produced almost 60% of the total electricity production since 2000 in Switzerland. They take part in the Energy Strategy 2050 due to their key role in the Swiss electricity market. According to this strategy, the mean annual hydropower production has to be increased by 1.5 TWh/year (under present framework) and by 3.2 TWh/year (under optimized conditions)
The Swiss storage power plants produced almost one third of the total production [SFOE, 2015].Furthermore, this type of plants, and specifically high head power plants (Figure 1), are useful to follow cyclic peak demands (daily, weekly and seasonal) as they can provide large amount of electricity in a short lapse of time. Owners and producers may consider an increase of the peak generation of these plants to reach the Energy Strategy 2050 and in order to adapt to the new renewable energy.

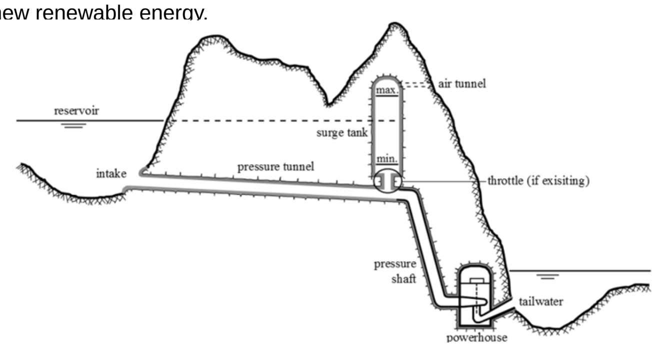

Figure 1 : Schematic view of a typical alpin high head power plant (H>200m) [Courtesy of A.J. Pachoud]

2. Throttled surge tanks

A surge tank is usually an excavated volume, which is connected to the waterway system and generally open to the atmosphere. The introduction of surge tanks allows reducing the construction cost of the pressure tunnel by minimising and reflecting the water hammer in/from pressure shaft. Mass oscillations appear between the upstream reservoir and the surge tank and could increase the time between two discharge variations.

Throttles are hydraulic devices accelerating the water flowing through and producing a given amount of head losses. The goal of a throttle placement is to keep extreme mass oscillations within the surge tank geometry (Figure 2).

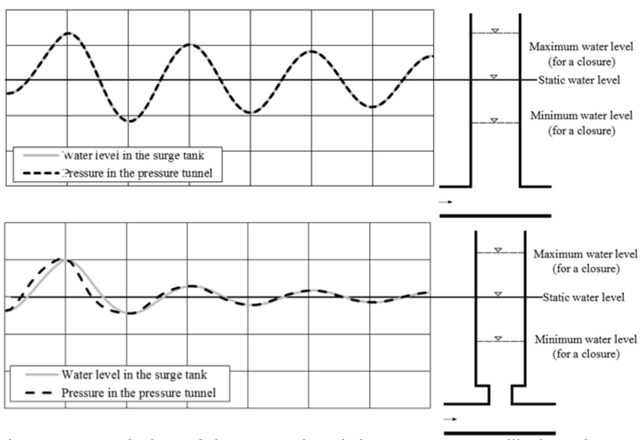

Figure 2 : Evolution of the water level due to mass oscillations in a simple surge tank (up) and a throttled surge tank (down)

The main disadvantage of the placement of a throttle is that the dynamic pressure produced by the water hammer increases in the pressure tunnel.

3. Different types of throttle

Throttles can be divided in, at least, three main categories: orifices, racks or vortex throttles. Orifices and racks can be either symmetric or asymmetric while vortex throttles are only asymmetric.

- Orifice: An orifice is a local geometry restrictions which may have different opening shape (circular, rectangular, etc.). The streamline expansion at the downstream is the same in all direction. Asymmetrical orifice shape allows introducing asymmetrical head losses up to 1:3 – 1:4.
- Rack throttle: A rack throttle is composed with a framework of parallel spaced bars or beams. The downstream streamlines expansion are forced in one direction. The different expansions should influence each others.
- Vortex throttle: This type of throttle is mainly present in Austrian surge tanks. It allows producing a higher asymmetry ratio up to 1:20 – 1:50 due to the complex swirling flow in the vortex throttle.

An orifice or a rack throttle could be placed during a refurbishment while vortex throttle must be placed during the construction due to its complexity

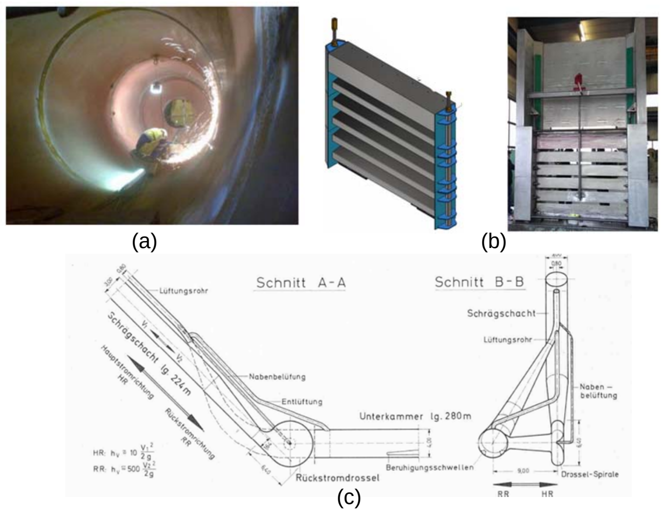

Figure 3 : Different existing throttles: (a) orifice in FMHL+; (b) Rack throttle in Gondo; and (c)Vortex throttle in Austria;

4. Conclusions and outlooks

The placement of a throttle is useful to manage the extreme water levels occurring during mass oscillations between the surge tank and the upstream reservoir. It allows reducing the construction cost and adapting an existing surge tank submitted to an increase of discharge in the waterway (during a refurbishment).

A research is performed at the LCH to build a catalogue of orifice geometries with physical and numerical experiments. The main goal is to improve the design of surge tank orifices by practical engineers.

Partners

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Publications

[1] Adam, N.J., De Cesare G. & Schleiss A.J., (2016). **Head loss coefficients trough sharp-edged orifices.** *In 28th IAHR Symposium on Hydraulic Machinery and Systems, Grenoble, France, July 4-8.*
[2] Adam, N.J., De Cesare G. & Schleiss A.J., (2016). **Experimental assessment of head losses trough elliptical and sharp-edged orifices.** *In 4th IAHR Europe Congress, Liège, Belgium, July 27-29.*
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