Numerical Simulation of the ALBA Synchrotron Light Source Cooling System Response to Pump Start-up and Shut-down

Xavier Escaler[1], David Juan[1], Joan Casas[2], Carles Colldelram[2], Marcos Quispe[2], Montserrat Prieto[2]

[1] UPC, 08028 Barcelona, Spain

[2] ALBA-CELLS Synchrotron, 08290 Cerdanyola del Vallès, Spain

Abstract

The ALBA Synchrotron Light Source cooling system is submitted to regular pump start-ups and shut-downs. Moreover, pumps can trip due to motor power failures. As a result, the piping system can be subjected to surges and pressure oscillations [1-2]. The 1D thermo-fluid simulation software Flowmaster® has been used to predict these transient conditions taking into account the fluid compressibility, the pipe elasticity, the characteristic time response of the check valves and the pump/motors moments of inertia.

On the one hand, during pump start-ups, significant pressure rises are detected, and based on the simulations made, the overpressure can be reduced by readjusting the PID controller parameters. On the other hand, unexpected pump shut-downs do not appear to provoke significant water hammer conditions.

However, pressure fluctuations are generated mainly in the same pumping line but also in the rest of the system due to the particular common return configuration. In all the cases the pressure regulation mechanisms acting on the pump rotating speeds serve to attenuate the consequences of these transients. Finally, the feasibility of the model to simulate the effect on the system response of trapped air inside the pipes has also been evaluated.

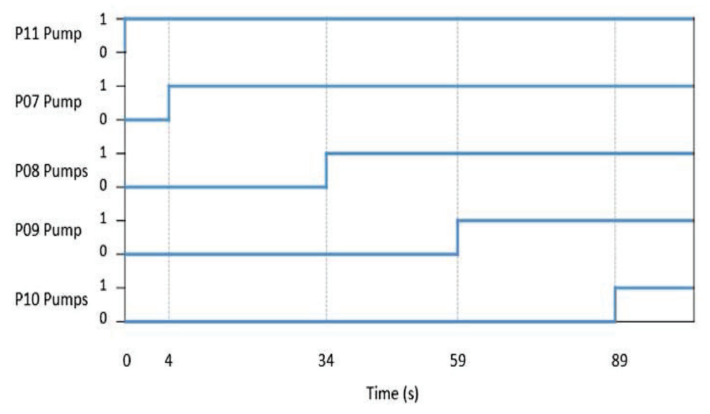
Numerical model

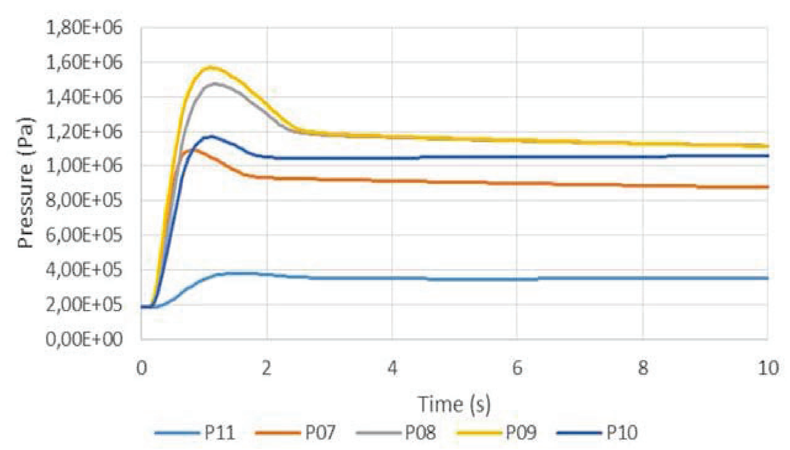
- The generation side of the cooling system is comprised of four pumping stations named P07, P08, P09 and P10. In P08 and P10 two pumps operate simultaneously in parallel, meanwhile in P07 and P09 only one pump is working. Another pump, P11, is in charge of delivering the hot water to the chillers that cool it down again.
- The moments of inertia for all the pumps and motors have been included in the model using Thorley empirical equations [3].
- The tilting disc check valves (non-return valves) mounted at the discharge pipe lines have also been modelled. To model them, a characteristic operating time of 1 s and a minimum flow velocity of 0.6 m/s were as-summed.
- In terms of pump pressures, PID controllers try to maintain the maximum values below a fixed set-point by regulating the pump's rotational speed. In terms of water temperature, a series of mixing valves and chillers ensure a temperature of 23ºC at the entrance of the consumption rings also by means of PID controllers acting on three-way valves and heat exchangers.

Simulated Response

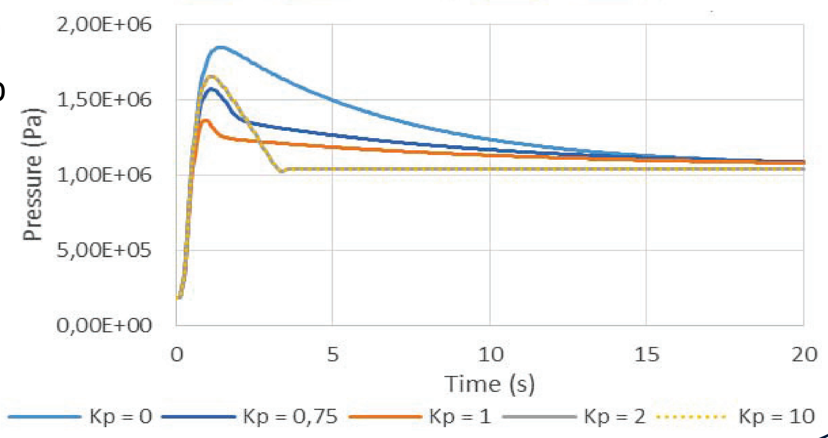
Normal pumping system start-up

- **Simulation of the current ALBA's synchrotron maneuver**
  - Five pumps starting sequentially during 100 s.
  - Pressure peaks generated at every pump outlet:
    - P09 reaches an overpressure of 54% its set point.
  - Possibility to damage the piping components due to overpressure at pump outlet.



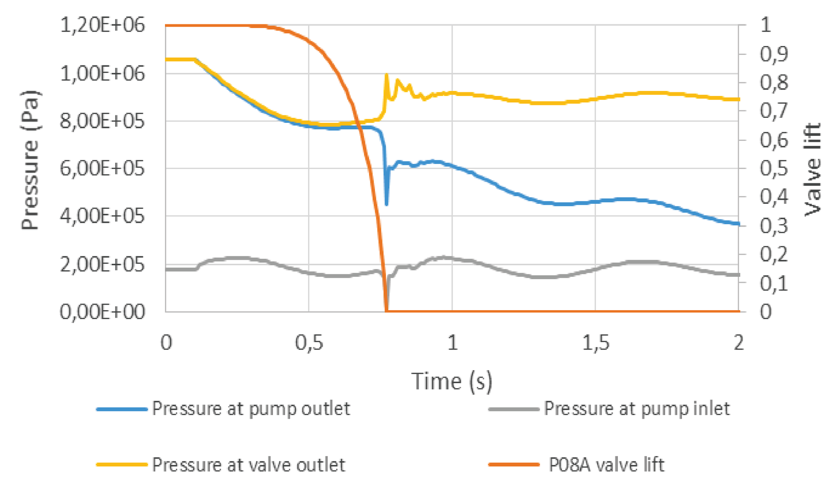


- **Modification of the PID parameters**
  - Reduction of the overpressure by 32% in P09 pump outlet can be achieved.



Pump trip without thermal load

- The effects of the unexpected shut-down of only one of the pumps in P08 station have been simulated without thermal demand and the mixing valves at 50% opening ratio.

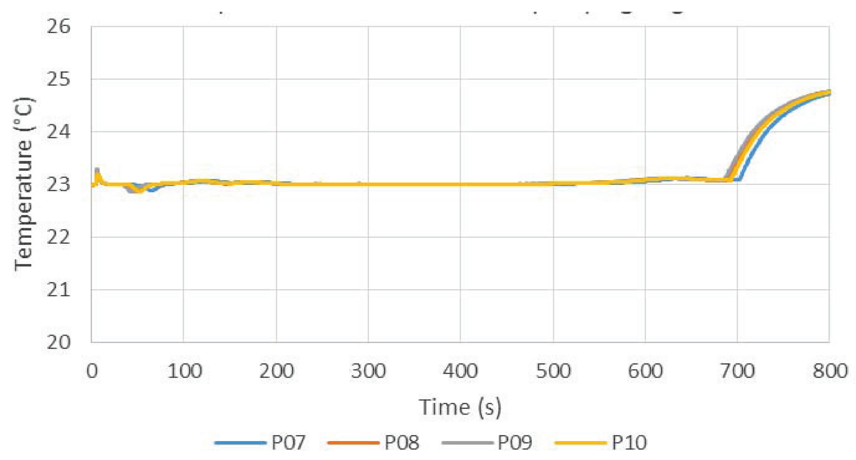


- Flow travels in reverse direction for 0.3 s.
- A disturbance is generated at the valve outlet due to its closure.
- Pressure might reach vapor pressure at pump inlet.

- Significant effect observed in P11 rotational speed and the common return pipe flow during the transient.
- At the end, the second P08 pump is capable of compensating the lack of flow from the tripped pump and the original pressure set point is achieved. However, this is not the case in P10 pumping line and at the end of the transient the system cannot maintain the nominal flow rate and delivery pressure.

Pump trip with thermal load

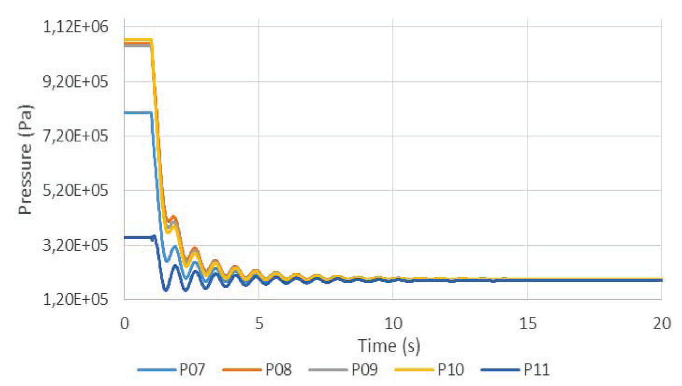
- In the case that the synchrotron light source is at full operation, the most critical case corresponds to a pump trip effecting P11 which is responsible of feeding the chillers to reduce the temperature of the cooling system water.
- It is significant to note that, due to the length of the pipe network, the consequences take around 600 s to reach the rings. At this end point, the system is obviously unable to cool the water anymore if P11 is not started again.



- At 600 s, the three-way valves start changing its opening due to the increase of the water temperature.
- At 700 s, these valves are opened only to the accumulator where the temperature starts raising.

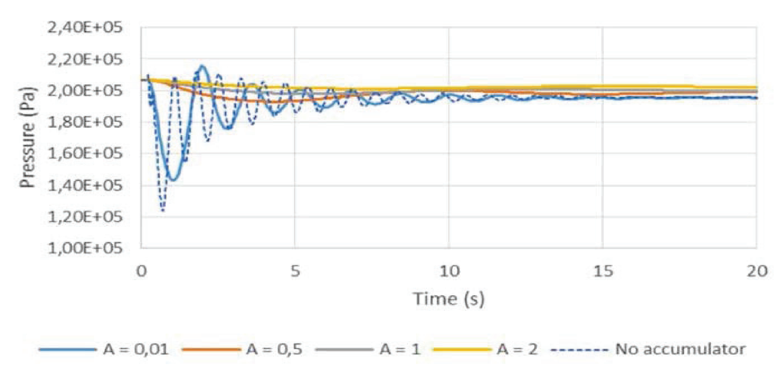
Simultaneous pumping system shut-down

- Some oscillations are detected in all the pumping lines but they are rapidly attenuated. This procedure is not currently being applied in ALBA, which is actually a sequential shut-down of the pumping lines what makes the consequences even softer.



Effect of trapped air

- The effect of air in the pipes has been analyzed during the pump shut-down and it has been confirmed that the transient pressure fluctuations predicted in the system are modified.



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[3] A.R.D. Thorley, Fluid Transients in Pipeline Systems. D&L George Ltd, U.K., 1991