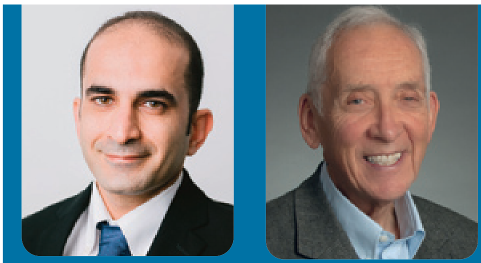
A LOOK AT SELECTED ONGOING WORK ON HYDRAULIC TRANSIENTS IN CLOSED CONDUITS

EDITORIAL BY HAMID BASHIRI & ANGELOS FINDIKAKIS

This issue of Hydrolink includes eight articles on different aspects of research and practice in hydraulic transients in urban and industrial systems. Hydraulic transients result from sudden changes in flow conditions in pipeline systems due to the planned or accidental closure/opening of valves or the start/stop of pumps or hydraulic turbines causing pressure waves through the system and pressure spikes that can be generated by column separation and rejoining.



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Failure to properly account for hydraulic transient effects can cause significant damage and accidents that may jeopardize personnel safety. In some cases, transients caused by operator error have resulted in equipment destruction and fatalities, such as the water hammer surge that caused the burst of penstock and three fatalities at the Oigawa Power Station in Japan in 1950. A more severe accident that was likely caused by hydraulic transients is the catastrophic destruction of the turbines of the Sayano Shushenskaya hydropower station in southern Siberia in 2009 killing 75 people, where, as discussed in the article by Hamill in this issue, a quite sudden wicket gate closure caused water column separation in the draft tubes of the turbines followed by extremely large pressure rise.

The systematic study of hydraulic transients in full flowing closed conduits and the resulting pressure waves often referred to as water hammer, goes back to the last quarter of the nineteenth century, starting with research on the flow of blood in arteries, which produced the basic formula relating the change in velocity to the change in pressure in closed conduits, and which later was developed independently by the Russian mathematician and engineer Nikolay Joukowsky working on engineered pipe systems.

Today, hydraulic transient analysis is an essential part of the design of pipeline systems in industrial facilities, including cooling water, firewater, or processing water systems, as well as for the design of pipes carrying other liquids, such as oil or liquified natural gas. The analysis of transients under different operation or accident scenarios produces the maximum pressure in each pipe segment of the system, which is used to select the pipe diameter and material. In addition, as pointed out in the article by Tijsseling in this issue, steep pressure wave fronts can cause structural motion which suggests that designs must account for dynamic fluid-structure interactions.

Equally important to the maximum pressures are the minimum pressures experienced during transients in a pipe system, which sometimes can become as low as the vapor pressure, causing cavitation. The cause and consequences of negative pressures caused by hydraulic transients are discussed in the article by Karney, in this issue.

Hydraulic transients are of special interest to the hydropower industry which is supporting research aimed at improving project design and operation.

An example is recent research on hydraulic transient problems in the nearly horizontal upper chambers of surge tanks of underground pumped storage power stations described in the article by Pummer and Richter. Three case studies illustrating the importance of hydraulic transient analysis for the operation of hydroelectric plants are presented in the article by Chaudhry, which also discusses mitigation options for each case. Experimental and numerical model work on hydraulic transients problems in hydropower systems has also been carried out at the Instituto Superior Técnico in Portugal and the Ecole Polytechnique Fédérale de Lausanne in Switzerland as discussed in the article by Ferras, de Cesare, Covas and Schleiss. Their article reports on laboratory tests to study the effect of fluid-structure interaction and air entrapment on the propagation of pressure waves in pipes. The same article also presents the findings of research aimed at using hydraulic transients theory to detect and locate weak zones in pipelines, i.e. parts of lower stiffness.

Hydraulic transients tests have been used by Meniconi, Capponi, Louati and Brunone for the detection of faults in pipelines, such as leaks, blockages, corroded parts or illegal connections. Their article describes laboratory work and the use of this approach to locate faults in two different pipeline systems in Italy.

Sizing structures and devices mitigating the impact of hydraulic transients must ensure the safety of the system but also avoid costly overdesign resulting from simplified analyses that neglect some of the factors affecting the response of such systems. An example of work aimed at avoiding such device overdesign is the work on surge vessels described in the article by van der Zwan and Pothof at Deltares, who are developing models that account for the effect of air temperature inside surge vessels on their performance. An article described their work will be published in the next issue of Hydrolink.

Hydraulic transients can also be of concern for the operation of stormwater systems, where, as pointed out in the article by Allasia, Pachaly, Tassi, Vasconcelos, Hodges, and Dickinson, a combination of poor design and the lack of maintenance allowing the formation of local blockages can cause street damage and dangerous conditions, especially when these systems have to handle rapidly accumulating runoff from strong convective storms.
The articles in this issue show that more than a century after the introduction of Joukowsky's equation, there are still many aspects of hydraulic transients that require further research. Laboratory work, advanced numerical models and new techniques, such as machine learning, are used to continue improving ways to optimize system performance and control the adverse effects of hydraulic transients.