

NUMERICAL COMPUTATIONS OF WATER HAMMER (HYDRAULIC TRANSIENT) IN PENSTOCKS OF HYDRAULIC TURBINES

Key words: hydraulic turbines, penstock, liquid transient flow calculation,
water hammer simulation, hydraulic transient simulation

Water hammer (or hydraulic transient) courses in the pipeline systems of hydraulic machines are simulated numerically using the HYDTRA (HYDraulic TRAnsients) computer code developed in the Szewalski Institute of Fluid-Flow Machinery in Gdansk. Basic assumption of the computational algorithm is that pipelines (delivery and suction conduits) are modelled as distributed elements and the hydraulic machine and its cut-off valve or bypass valve - as lumped elements. The method of characteristics (MOC) is applied for solving equations governing the unsteady liquid flow in the pipelines. Static characteristics of an analyzed machine in the wide range of unit parameters (unit rotational speed n_{11} , unit discharge Q_{11} and unit torque M_{11}) are needed to perform calculation. Such an approach is typical in the hydraulic transient analyses. The code has been validated on several occasions using numerous experimental results. The discrepancy between calculation and experimental data is usually below a few percent.

HYDTRA was used for examples for:

- optimisation of the wicket gate (guide vane) closure course of pump-turbines in order to protect penstocks from the excessive pressure rise, and motor-generator from the excessive rotational speed increase,
- analysis of by-pass valve application in order to diminish water hammer level

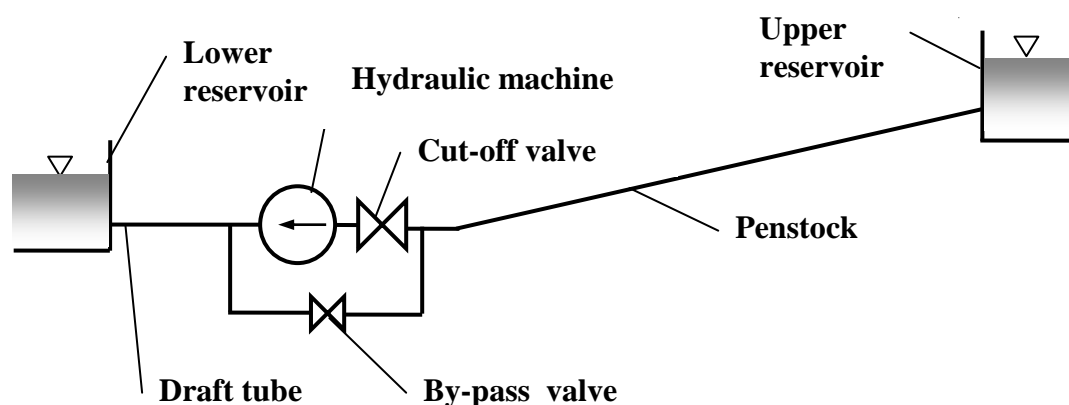


Fig. 1 Layout of the flow system considered in HYDTRA code

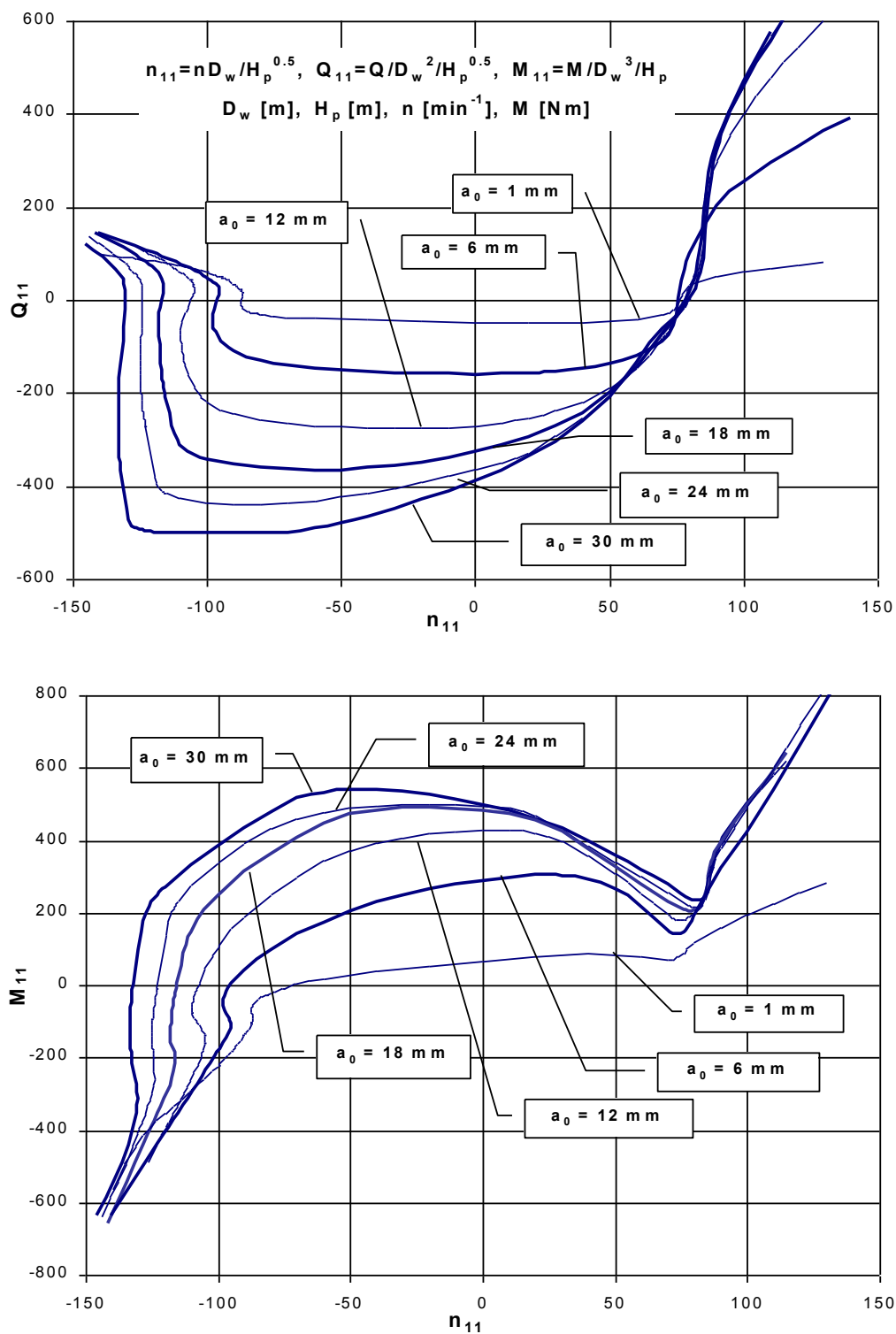


Fig. 2 An example of four-quadrant steady-state characteristics of a pump-turbine.

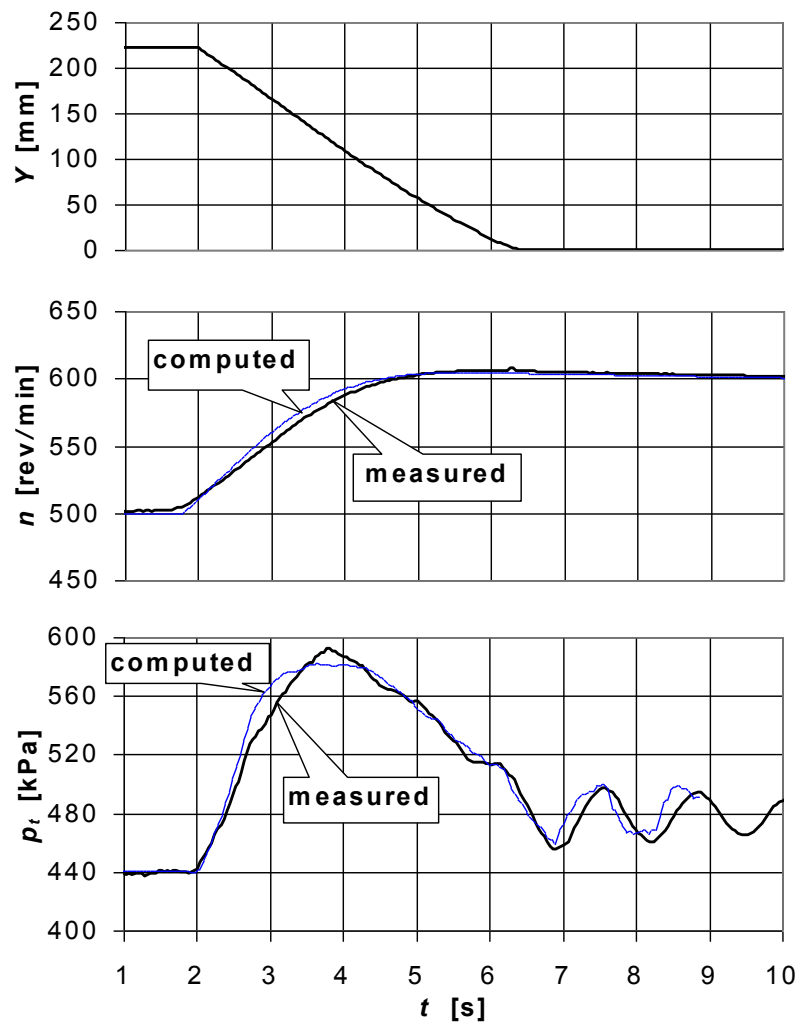


Fig. 3 The comparison between the recorded and calculated curves of pressure in the penstock (p_t) and runner speed (n) during a turbine load rejection.

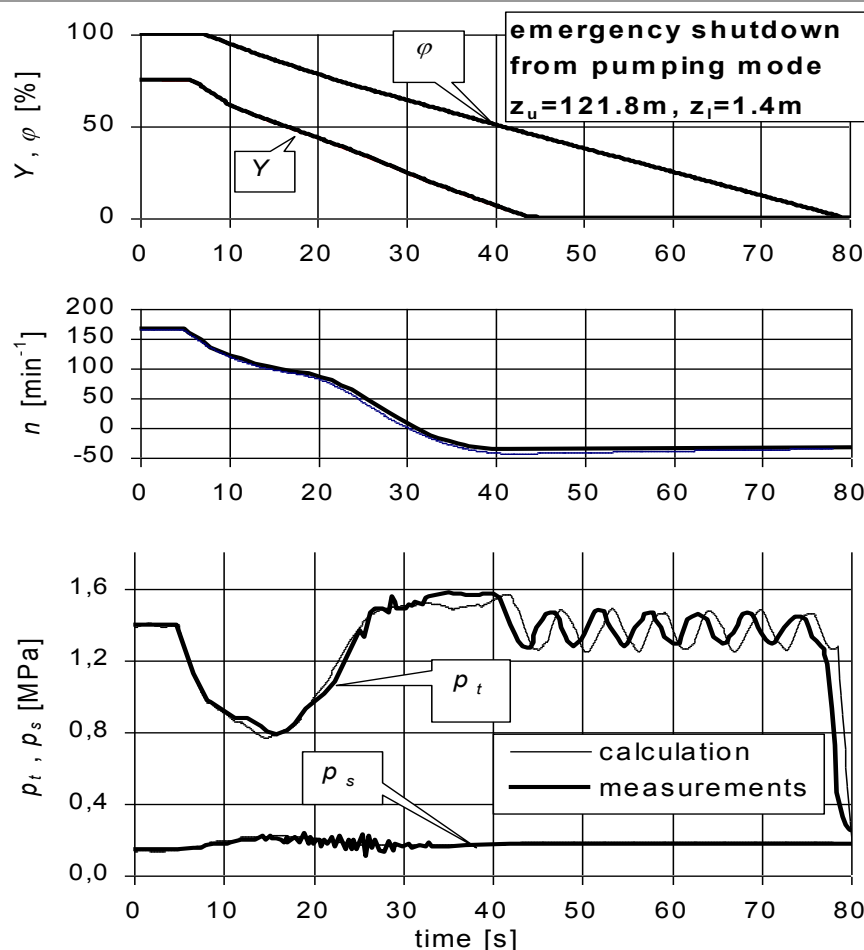


Fig. 4 An exemplary comparison between calculation and measurement results for an emergency shutdown of from a pumping mode of operation

References:

- Adamkowski, A.: *Case Study: Lapino Powerplant Penstock Failure*, ASCE Jour. of Hydraulic Engineering, July 2001, Vol.127, No.7, pp. 547-555. – [pdf version](#)
- Adamkowski, A., Lewandowski M.: *Flow conditions in penstocks of a pumped-storage power plant operated at a reduced head water level*, Proc. of Int. Conf. HYDROTURBO'2001, Podbanske, October 9-11 2001, pp. 317-328. – [pdf version](#)
- Adamkowski, A.: *Investigation of waterhammer suppression in a pumping system by means of an air chamber*, Proc. of I Intern. Scientific and Technical Confer. on TECHNOLOGY, AUTOMATION and CONTROL OF WASTEWATER and DRINKING WATER SYSTEMS TiASWiK'02, Gdansk- Sobieszewo, pp. 167 - 173. – [pdf version](#)
- Adamkowski, A.: *Analysis of transient flow in pipes with expending or contracting sections*, ASME Journal of Fluid Engineering, July 2003, pp. 716-722. – [pdf version](#)
- Adamkowski A., Lewandowski M.: *Experimental examination of unsteady friction models for transients pipe flow simulation*, ASME Journal of Fluid Engineering", Nov. 2006, Vol. 128, pp. 1351-1363. – [pdf version](#)
- Marcinkiewicz, J., Adamowski, A., Lewandowski, M.: *Experimental Evaluation of Ability of Relap5, Drako®, Flowmaster2TM and Program Using Unsteady Wall Friction Model to Calculate Water Hammer Loadings on Pipelines*, Nuclear Engineering and Design 238(2008), pp. 2084-2093 – [pdf version](#)

Adamkowski A., Lewandowski M., *A new method for numerical prediction of liquid column separation accompanying hydraulic transients in pipelines*, ASME Journal of Fluid Engineering , ASME, 131(7), June, pp. 071302-1-071302-11. – [pdf version](#)

Adamkowski A., Lewandowski M.: *Improved numerical modelling of hydraulic transients in pipelines with column separation*, 3rd IAHR International Meeting of the Workgroup on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems, October 14-16, 2009, Brno, Czech Republic, pp. 419-431. – [pdf version](#)

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