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ABSTRACT

Self-Excitation Mechanisms for Pressure-Relief-Valves with attached Fluid-Columns

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Pressure Relief Valves (PRV) are common, passive safety devices used in process industries to safeguard pressurized vessels from overloading. Upon reaching a pre-set valve-opening pressure, the fluid lifts a spring-charged valve and escapes through the PRV out of the vessel. Despite its basic principle of operation, PRVs are sometimes found to display violent dynamics where the valve-tappet hammers repetitively onto the nozzle – with negative effects on the structure and the safety-performance of the valve.
Previous research focused on the valve as the primary source of these oscillations. The approach described in this article further includes its in- and out-going fluid columns and the pressure vessel. For the fluid, differential equations describing the conservation of mass and momentum in a 1D-viscous flow along with a linear transient dependence of density on fluid pressure have been considered to derive a finite-element model. For the sake of simplicity of the computational model, influences due to changes in temperature have not been considered. The valve is described by a 1-degree-of-freedom model for the valve-tappet with an appropriate contact formulation. The valve-gap drives the loss-term for the fluid-flow and the pressures act as resultant forces on the tappet. The non-linearity of the considered fluid-flow model, which is primarily due to the convective term in the equation of conservation of linear momentum, when combined with the contact formulation for the tappet and the coupling equations for both, lead us to a set of equations of motion which are nonlinear for both fluid and tappet.
These equations can be summarized as a set of nonlinear, first-order differential equations, which we solve numerically as an initial value problem.
We find solutions which display high-frequency self-excited oscillations. Our parameter studies indicate that self-excitation can be attributed to interrelated ranges of critical design parameters.

M. E. Gurtin, E. Fried & L. Anand: “The Mechanics and Thermodynamics of Continua” (Cambridge University Press, 2010).

C.J. Hös, A.R. Champneys, K. Paul and M. McNeely: “Dynamic behavior of direct spring-loaded pressure relief valves in gas service” in Journal of Loss Prevention in the Process Industries, (Elsevier 2014).