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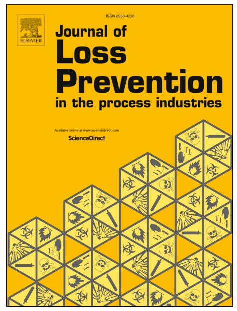

Dynamic behaviour of direct spring loaded pressure relief valves in gas service: II reduced order modelling

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Dynamic behaviour of direct spring loaded pressure relief valves in gas service: II reduced order modelling☆

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Abstract

A previous study of gas-service direct-spring pressure relief valves connected to a tank via a straight pipe is continued by deriving a reduced-order model for predicting oscillatory instabilities such as valve flutter and chatter. The reduction process uses collocation to take into account a finite number N of acoustic pressure waves within the pipe, resulting in a set of $2N+3$ ordinary differential equations. Following a novel non-dimensionalization, it is shown analytically that the model can exhibit, at experimentally realistic parameter values, instabilities associated with coupling between the valve and acoustic waves in the pipe. The thresholds for each instability are such that for a given flow rate, the first mode to go unstable as the inlet pipe length increases is the quarter-wave mode, then a three-quarter wave, a 5/4-wave etc. Thus the primary mode of instability should always be due to the quarter wave. In the limit of low flow rates, a simple approximate expression is found for the quarter-wave instability threshold in the form of inlet pipe length against mass flow rate. This threshold curve is found to agree well with simulation of the full model. For higher flow rates there is a need to include fluid convection, inlet pressure loss and pipe friction in order to get good agreement. The reduced model enables the dependence of the stability curve on key dimensionless physical parameters to be readily computed.

Keywords: pressure-relief valve, reduced order modelling, instability, quarter-wave, Hopf bifurcation, acoustic resonance,

☆Short title: Reduced order modelling of gas PRVs