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# A Numerical Thermal-Hydraulic Model to Simulate the Fast Transients in a Supercritical Water Channel Subjected to Sharp Pressure Variations

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**Abstract.** The present work demonstrates the extension of a thermal-hydraulic model, THRUST, with an objective to simulate the fast transient flow dynamics in a supercritical water channel of circular cross section. THRUST is a 1-D model which solves the nonlinearly coupled mass, axial momentum and energy conservation equations in time domain based on a characteristics-dependent fully implicit finite difference scheme using an Eulerian approach. The model developed accounts for the compressibility of the supercritical flow by considering the finite value of acoustic speed in the solution algorithm and treats the boundary conditions naturally. A supercritical water channel of circular cross section, for which the experimental data is available at steady state operating conditions, is chosen for the transient simulations to start with. Two different case studies are undertaken with a purpose to assess the capability of the model to analyze the fast transient processes caused by the large reduction in system pressure. The first transient case study is where the initial exit pressure is reduced by 1 $MPa$ exponentially in a time span of 5 $s$. In the second case study, the transient is initiated with a sudden step decrease in the exit pressure by the same amount. Results obtained for both the case studies show the desired performance from the model developed.

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**Key words**: Thermal-hydraulic model, supercritical water, fast transients due to large reduction in system pressure.

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# 1 Introduction

The study of supercritical water, though has been carried out extensively through many research works, primarily the experimental ones [1,2], in last several decades, poses many challenges still to-date. The prediction of thermal-hydraulic (TH) behavior on the occasion of fast transient processes is one of such issues. Moreover, the related study has generated a renewed interest at present in the scientific community. The worldwide effort to develop a supercritical water reactor (SCWR), which potentially can provide the improved thermal efficiency at a reduced price and lower maintenance, has triggered the inspiring motivation to the researchers. The various numerical research works [3, 4] carried out recently confirm that the sharp variation of thermo-physical properties of supercritical fluid (SCF) close to the pseudo-critical point (PCP) is an important factor which makes the predictive assessment more difficult. Therefore, it is natural to expect that the significant change in TH behavior of supercritical water (SCW) may take place in the event of transients initiated due to large change in system pressure. It is to be noticed that the fast transient process caused by the large reduction in system pressure is a common phenomenon in case of loss of coolant accident (LOCA) scenario likely to occur due to pump failure or leakage in the piping system of a SCWR plant. On the other hand, the available literature shows that there are numerous research works related to SCF which mainly confined to steady state analysis and investigation of density wave instability [5,6] in SCWR channels where neither the fast transient process took place nor it was caused due to large change in system pressure. However, fast transient depressurizing events have recently been studied experimentally [7] and numerically [8, 9] for another supercritical fluid, $CO_2$, used for the application of carbon capture and storage, different from the SCWR technology. The studies were carried out to analyze the effect of leakage of supercritical $CO_2$ into the ambient air in the event of an accidental crack in a pipe line caused during its transportation.

The present investigation is carried out with the objective to analyze the TH behavior of SCW, flowing in a vertically upward circular tube, in the event of transients caused by large reduction in system pressure with the help of an in-house transient Thermal-Hydraulic solveR Undertaking Supercritical waTer (THRUST). THRUST has already been validated [10,11] by comparing the results with the available experimental data, and with the Fluent based CFD results and the available numerical results. Two case studies are undertaken, one where transient is initiated due to gradual, but large decrease of the exit pressure by $1MPa$ and for the other one, there is sudden step decrease in the exit pressure by the same amount.

# 2 Numerical model development

THRUST is a 1-D model developed to take into account the variation of field variables in the axial direction.