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Two phase flow redistribution in a two-layered porous medium with contrasting permeability

Ali Swaidan[a,], Florian Fichot[a], M. Quintard[b]

[a]Institut de Radioprotection et de Sûreté Nucléaire (IRSN) - PSN-RES/SAG/LEPC - Cadarache bât. 702 - 13115 St Paul-lez-Durance, FRANCE
[b]Université de Toulouse - INPT - UPS - Institut de Mécanique des Fluides de Toulouse (IMFT) - Allée Camille Soula, F-31400 Toulouse, FRANCE
* Corresponding author. Email: ali.swaidan@irsn.fr

ABSTRACT motivated to investigate debris bed coolability in a damaged nuclear reactor core by bottom reflooding, this paper studies the physical situation involving injection of water into a superheated particle bed leading to high velocity flow of steam. The particle bed is composed of two cylindrical concentric parts and stratified vertically. One of the particular features of the studied configuration is that quenching of the superheated particles generates a strong flow of steam which may create a vertical pressure gradient leading the water in the lateral, more permeable medium, to flow faster than the injection velocity and consequently reducing the efficiency of cooling. The aim is to propose an analytical model to predict the behavior of water entrainment in the lateral layer (bypass) of larger permeability and porosity. This model computes the quench front velocity, water-to-steam conversion ratio, and the velocity of water in the bypass. It provides good qualitative and quantitative results for the two-phase flow redistribution as compared to experimental data. It also has several advantages as it allows: performing fast evaluations of the efficiency of cooling, upscaling to reactor-scale straightforwardly, and performing sensitivity studies on the physical properties of the particle beds and the fluid, and the variations of the momentum equations. For instance, it showed that the Generalized Darcy law was not sufficient to obtain acceptable evaluations whereas considering non-zero cross-terms in the Darcy Forchheimer equation by including an interfacial friction law succeeds in obtaining better results.

Keywords: Reflooding, Two-phase flow, Porous media, Bypass, Water entrainment