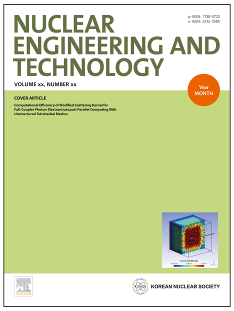

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Investigation of Flow Regime in Debris Bed Formation Behavior with Non-Spherical Particles

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Abstract

It is important to clarify the characteristics of flow regimes underlying the debris bed formation behavior that might be encountered in Core Disruptive Accidents (CDA) of Sodium-cooled Fast Reactors (SFR). Although in our previous publications, by applying dimensional analysis technique, an empirical model, with its reasonability confirmed over a variety of parametric conditions, has been successfully developed to predict the regime transition and final bed geometry formed, so far this model is restricted to predictions of debris mixtures composed of spherical particles. Focusing on this aspect, in this study a new series of experiments using non-spherical particles has been conducted. Based on the knowledge and data obtained, an extension scheme is suggested with the purpose of extending the base model to cover the particle-shape influence. Through detailed analyses and given our current range of experimental conditions, it is found that, by coupling the base model with this scheme, respectable agreement between experiments and model predictions for the regime transition can be achieved for both spherical and non-spherical particles. Knowledge and evidence from our work might be utilized for the future improvement of design of an in-vessel core catcher as well as the development and verification of SFR severe accident analysis codes in China.

Key words: Sodium-cooled Fast Reactor, Core Disruptive Accident, Debris Bed Formation, Flow Regime, Non-Spherical Particles

1. Introduction

During the material relocation phase of a hypothetical Core Disruptive Accident (CDA) of a Sodium-cooled Fast Reactor (SFR), molten core materials, because of their gravity-driven discharge through potential paths, may relocate into the sodium plenum. These materials settle to form debris beds on the core-support structure and/or in the lower inlet plenum of the reactor vessel [1, 2], as depicted in Fig. 1. Sufficient cooling of the formed debris beds, as well as their neutronically subcritical configuration, is necessary for In-Vessel Retention (IVR) of degraded core materials.

To prevent the penetration of the reactor vessel by molten fuel, and to distribute the molten fuel or core debris formed in a CDA into non-critical configurations, in-vessel retention devices (e.g. the core catcher) are used in some SFR designs [1, 3]. Although the detailed structure of the core catcher (e.g. single-layer or multi-layer) might be different depending on the reactor-type in different countries [4-6], it is expected that during a postulated CDA, after being quenched and fragmented into fuel debris in the lower plenum region, the formed fuel debris will be accumulated on the layers of the in-vessel core catcher [1]. To stably remove the decay heat generated from the debris bed on the core catcher, thus, the size, retention capability and structure of the catcher should be carefully designed.