3D Coupled Transient simulation of a Fast Liquid Fuel Molten Salt Reactor Primary Loop Using GeN-Foam

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ABSTRACT

In the recent years, Computational Fluid Dynamics (CFD) has become an important tool in modeling of nuclear reactors. In this study, a three-dimensional (3D) fast spectrum Liquid Fuel Molten Salt Reactor (LFMSR) primary loop is modelled to simulate transient scenarios that are relevant from the safety point of view using the new multi-physics solver Generalized Nuclear Foam (GeN-Foam). GeN-Foam is built based on the C++ open-source library for the solution of continuum mechanics problems OpenFOAM. The code utilizes a unified fine/coarse mesh approach based on porous medium equations modeling the different physics such as neutron kinetic, thermal hydraulics and structural thermal mechanics. The standard k–ε turbulence model has been used for this study, and a chloride-based fuel salt has been selected for its good thermophysical properties and for its low moderating power that make it a perfect candidate for the fast spectrum LFMSR reactors. The proposed LFMSR is based on eight symmetrical loops therefore just one eighth of the reactor has been simulated. The GeN-Foam coarse mesh approach, based on the porous media equations, is used for modeling all the different components of the primary loop including the reactor active core, heat exchanger, and the pump. An Unprotected Loss of Flow accident (ULOF) in which the pump head has been instantaneously reduced to zero has been selected to test the reactor in one of the most challenging possible situations. The obtained results confirm GeN-Foam capabilities in performing coupled LFMSR transient analysis and its validity as a tool for the design analysis and optimization. Although the current design needs further assessment and development, it showed encouraging performance during the ULOF simulation paving the way to the next step in the optimization process.

KEYWORDS
CFD, GeN-Foam, LFMSR, Multi-physics

1. INTRODUCTION

Liquid fuel molten salt reactor (LFMSR) is recognized as one of the generation IV reference reactors thanks to its inherent safety and better performance such as low pressure operation, high boiling temperature and for the chloride based salt reactors; no hydrogen generation during an accident [1] [2]. Modeling these