Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 131 (2017) 86–93

Energy Procedia

www.elsevier.com/locate/procedia

5th International Symposium on Innovative Nuclear Energy Systems, INES-5, 31 October – 2 November, 2016, Ookayama Campus, Tokyo Institute of Technology, JAPAN

Thermal-hydraulic Feasibility Study of a Convex shaped Fast Reactor Core

Keiko CHITOSE*, Hiroyasu MOCHIZUKI, Naoyuki TAKAKI

Nuclear Safety Engineering, Tokyo City University
1-28-1 Tamazutsumi, Setagaya-ku, Tokyo 158-8557, Japan

Abstract

The objective of the present study is to evaluate the temperature profile of a convex shaped reactor core to confirm the thermal hydraulic feasibility. The convex core configuration intends to achieve negative reactivity insertion by fuel compaction in case of CDA. For the preliminary study, a convex core with fuel length 1.585m in the inner-core region and 0.52m in the outer-core region is modeled by RELAP5-3D code. The calculation model consists of the reactor core with 10 different channels, two IHXs, two main pumps, and lower and upper plena. The basic parameters are assumed similar to the existing study for Monju and JSFR. Considering well-balanced flow distribution to the core, the linear heat rate of the outer-core region is within the upper limit. The pressure loss and temperature distribution of the core are calculated. It is confirmed that no major issue to deny the feasibility of the fundamental thermal-hydraulics.

Keywords: Fast reactor; Convex shaped core; Thermal-hydraulic feasibility; Recriticality

1. Introduction

The fuel in fast reactors is not always arranged in its most reactive configuration, some early studies are focused on elimination of the recriticality. Until now, a concept of the Japan Sodium-cooled Fast Reactor (JSFR) has been

* Corresponding author. Tel.: 81-3-5707-0104
E-mail address: g1691001@tcu.ac.jp

10.1016/j.egypro.2017.09.453

proposed by a consortium of Japan Atomic Energy Agency (JAEA) and Japan Atomic Power Company (JAPC) [1]. This reactor has a measure to discharge melted fuel using a small duct provided at the corner of a wrapper tube in order to rule out the recriticality. This component is named as FAIDUS (Fuel Assembly with Inner-Duct Structure) and several design options including configurations were studied [2, 3]. The effectiveness of the FAIDUS is evaluated based on the out-of-pile tests and an in-pile test [4]. The evaluation methodology of severe accident phenomena, fuel discharge behavior and counter measures are developed [5-7]. It is shown that a possibility of the recriticality could be neglected when a large scale fuel melt occurred due to unprotected loss of flow (ULOF) of the JSFR [8]. However, several number of fuel pins should be withdrawn from a fuel subassembly (SA) in order to make a space for the duct. On the other hand, inherent safety concepts, such as reactivity feedback, natural circulation of coolant and dispersal of failed reactor fuel were investigated [9]. Instead of the measures, a special core configuration such as a convex shaped core has been studied from the stand point of the neutronics because this core shape possibly can avoid the recriticality by increasing neutron leakage, when a fuel compaction occurs at an initial stage of a transient event such as an unprotected loss-of-flow (ULOF) [10].

The convex shaped core has a feature that fuel length in an inner-core region is longer than that in an outer-core region. Since total fuel SA length including upper and lower blanket regions, gas plenum, stainless shield and outlet region are different in inner-core region and outer-core region, the core restraint system should be examined. The detailed design for the shorter SA will be investigated in future. The fuel length in inner-core region becomes longer than the fuel length designed for the JSFR. Therefore, a pressure loss over the longer SA should be investigated. Furthermore, since the outer core region has to share high linear heat rate, thermal-hydraulics of the whole core should be investigated.

In order to confirm the feasibility of the thermal hydraulics, the RELAP5-3D Ver.4.3.4 is used. The physical property data of sodium in this version is modified considerably. First, the JSFR core is modeled as the reference, and the basic calculation model simulates the primary heat transport system of the JSFR. Two secondary heat transport systems connected to the primary heat transport system by intermediate heat exchangers (IHXs) are modeled as simple flow channels of which ends are given by boundary conditions. In order to compare the pressure loss over the SA, a standard fuel SA with 0.75 m fuel length is calculated as the reference JSFR. Then, the characteristics of the convex shaped core are investigated comparing to this reference plant.

2. Fuel subassembly

A precise configuration of a fuel SA is not shown in the report of JAEA-Evaluation [11]. In order to assess the thermal-hydraulics using the RELAP5-3D code, we make some assumption for the configuration of the JSFR SA. Since it is mentioned in the document that diameter of the fuel pin, thickness of the wrapper tube and total number of fuel pin are 9.3 mm, 5 mm and 315 respectively, the dimensions of the fuel SA for the assessment is determined based on the concept of the fuel SA design of “Monju”. Since the number of fuel pins withdrawn for the FAIDUS is 16, the total number of fuel pins in the SA becomes 331. If the values for JSFR are not described in the report, the dimension of Monju are adopted. The dimensions of the analytical model are as listed in Table 1.

Table 1. Dimensions of fuel subassemblies

Item	Monju	JSFR	Calculation model
Total number of fuel SA	198	562	122/440
Total number of radial blanket	172	96	96
Total number of fuel pin in one SA	169	315	331
Outside diameter of cladding (mm)	6.5	9.3	9.3
Thickness of cladding (mm)	0.47	no description	0.5
Gap between pellet and cladding (mm)	0.08	no description	0.08
Outside diameter of pellet (mm)	5.4	no description	8.14
Wire spacer diameter (mm)	1.3	no description	1.3
Gap between spacer and wall or cladding (mm)	0.08	no description	0.08
Thickness of wrapper tube (mm)	3.0	5.0	5.0
Gap between wrapper tubes (mm)	5.0	no description	5.0
Driver fuel length (m)	0.935	0.75	1.0/0.5
Blanket length (m) (upper/lower)	0.3/0.35	0.4/0.5	0.3/0.4
Maximum linear heat rate (W/cm)	360	419	less than 419