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Safety Evaluation of UCFR-1000 MWe with MATRA-LMR

Han Seo, Sarah Kang, In Cheol Bang*
Ulsan National Institute of Science and Technology (UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan Metropolitan City 689-798, Republic of Korea
**Corresponding author: icbang@unist.ac.kr*

1. Introduction

Ultra-long Cycle Fast Reactor (UCFR) is the long-life nuclear reactor without refueling. The concept of UCFR is based on the breed and burn system. The shapes of neutron flux and power density remain constant but they move their position every moment. Sekimoto et al. [1] proposed the CANDLE reactor, which is the basic concept of UCFR. Like CANDLE reactor, Traveling Wave Reactor (TWR) was also introduced as a concept of new reactor [2]. Tak et al. [3] proposed the preliminary concept of UCFR which can produce 1000 MWe. The fuel rod is composed of U-10Zr, the cladding material is HT9, and the coolant is sodium.

MATRA-LMR (Multichannel Analyzer for Transient and steady-state in Rod Array for Liquid Metal Reactor) was developed as a subchannel analysis code to calculate the thermal-hydraulic characteristic of liquid metal reactors such as fuel, cladding, and coolant temperatures [4].

In this study, with MATRA-LMR code, the major properties of UCFR-1000 MWe are calculated and compared with KALIMER-600 MWe. Also, the safety margin of UCFR-1000 MWe is analyzed using safety regulation table.

2. UCFR-1000 MWe and MATRA-LMR

UCFR-1000 MWe is designed to operate 60 years without refueling. The power density moves to axial direction during 60 years with a same speed. The parameters in 0 year, 30 year, and 60 year are evaluated for safety limits.

2.1 UCFR-1000 MWe

Table I shows the major core parameters of UCFR-1000 MWe. The operating period of UCFR-1000 MWe is 60 years without refueling. UCFR-1000 MWe has 378 drivers, 13 primary controls, 6 secondary controls, and 234 reflectors. Figure 1 shows one assembly of UCFR-1000 MWe.

2.2 MATRA-LMR code

MATRA-LMR code requires to define the subchannels which are filled with coolant. As shown in Fig. 1, there are 186 subchannels are existed in one assembly.

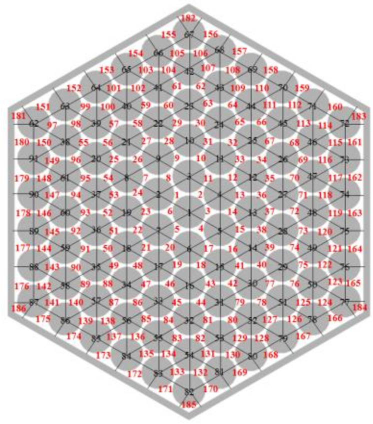

Fig. 1. One assembly of UCFR-1000 MWe

Table I: Major Parameters of UCFR-1000 MWe

		UCFR
Core	Core thermal output (MWth)	2600
	Core electric power (MWe)	1000
	Core inlet temperature (^oC)	427
	Active core height (mm)	3600
	Core diameter (mm)	4800
	Pins per fuel assembly	91
Pins	Total axial height (mm)	3600
	Rod outer diameter (mm)	14.9
	Pitch / diameter	1.075
	Wire wrap diameter / lead (mm)	1.2/300
	Cladding thickness (mm)	0.5
	Duct wall thickness (mm)	3
	Duct inside flat to flat distance (mm)	156

3. Analysis Results

3.1 MATRA-LMR Results

Fuel rod temperature, cladding temperature, and coolant temperature of UCFR-1000 MWe are calculated and compared with ones of KALIMER-600 MWe. The peaking factor is considered as 1.4 in the analysis because of the limitation of application range of the code even though the value obtained in the nuclear design was 1.8. Most of results are the properties of rod #1 which is the center rod of one assembly. Figure 2 shows the normalized power with normalized distance. The maximum normalized power in 0th year is four times higher than one of KALIMER. Figure 3 shows the axial fuel rod temperature according to distance. Compared with KALIMER, the temperature profile of UCFR fuel is higher due to high average heat flux for UCFR. Figure 4 shows the cladding temperature distribution of UCFR and KALIMER. As shown in Fig. 4, the highest cladding temperature of UCFR is 885 °C and KALIMER is 667 °C. Figure 5 shows the temperature profile from fuel rod to cladding where the maximum heat flux is generated.

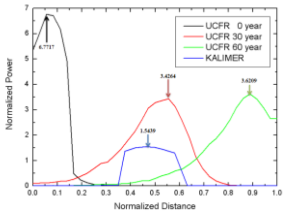

Fig. 2. Normalized power with normalized distance

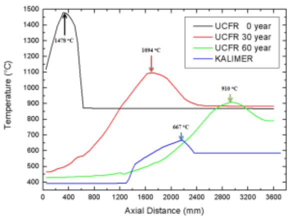

Fig. 3. Axial rod temperature where the maximum heat flux is generated (rod #1).

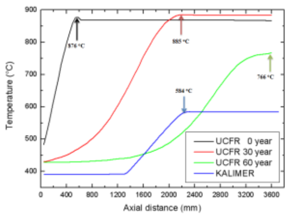

Fig. 4. Cladding temperature along with axial distance (rod #1).

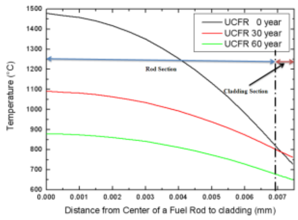

Fig. 5. Temperature profile from rod center to cladding (rod #1).

3.2 Safety Evaluation of UCFR-1000 MWe

Safety Evaluation of UCFR is based on the report which is published by KAERI [5]. Table II shows the limitation of each parameters and UCFR results.

Table II: Major Parameters of UCFR-1000 MWe

Temperature	UCFR (°C)	Limitation (°C)
Max. Coolant	867	560
Max. Cladding	876	650
Max. Fuel rod	1479	955

4. Conclusions

The following results are obtained.

(1) The current design of UCFR-1000 MWe does not satisfy the safety requirements, whereas KALIMER-600 MWe keeps the desirable safety margin. It is the original limitation as a technical barrier in developing a long-life core fast reactor.

(2) To satisfy the design limitation of such type of reactor, the total thermal output should be decreased or the other concepts such as changing the number of pins per assembly should be needed.

(3) An inverted assembly concept based on block type fuel/channel could be a solution.

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