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AIP Conference Proceedings

4TH INTERNATIONAL CONFERENCE ON ADVANCES IN NUCLEAR SCIENCE AND ENGINEERING (ICANSE 2013)

- **Conference date:** 16–19 September 2013
- **Location:** Denpasar, Bali
- **ISBN:** 978-0-7354-1251-4
- **Editors:** Zaki Su'ud and A. Waris
- **Volume number:** 1615
- **Published:** 30 September 2014

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Source: AIP Conf. Proc. **1615**, 47 (2014); http://dx.doi.org/10.1063/1.4895859

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+ VIEW DESCRIPTION

Power flattening on modified CANDLE small long life gas-cooled fast reactor

Fiber Monado, Zaki Su'ud, Abdul Waris, Khairul Basar, Menik Ariani, and Hiroshi Sekimoto

Citation: AIP Conference Proceedings **1615**, 47 (2014); doi: 10.1063/1.4895859
View online: http://dx.doi.org/10.1063/1.4895859
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1615?ver=pdfcov
Published by the AIP Publishing

Power Flattening on Modified CANDLE Small Long Life Gas-cooled Fast Reactor

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Abstract. Gas-cooled Fast Reactor (GFR) is one of the candidates of next generation Nuclear Power Plants (NPPs) that expected to be operated commercially after 2030. In this research conceptual design study of long life 350 MWt GFR with natural uranium metallic fuel as fuel cycle input has been performed. Modified CANDLE burn-up strategy with first and second regions located near the last region (type B) has been applied. This reactor can be operated for 10 years without refuelling and fuel shuffling. Power peaking reduction is conducted by arranging the core radial direction into three regions with respectively uses fuel volume fraction 62.5%, 64% and 67.5%. The average power density in the modified core is about 82 Watt/cc and the power peaking factor decreased from 4.03 to 3.43.

INTRODUCTION

CANDLE (Constant Axial shape of Neutron flux, nuclide densities, and power shape During Life of Energy production) is a strategy of burn-up fuel in a nuclear power reactor core which is analogous to the burning of a candle [1, 2]. MCANDLE (Modified CANDLE) concept is a modification of the CANDLE method by introducing discreet regions and modification of shuffling scheme. MCANDLE burn-up concept was first introduced in the following references[3, 4]. In this research we adopted MCANDLE type B in which first and second regions are located near 10th region[5].

GFR is one of the candidates next generation of Nuclear Power Plants (NPPs) that is still in development and expected to go to commercial after 2030 [6]. In this study, we conducted power flattening of small long life GFR with the power 350 MWt which have R-Z cylinder geometry. Its type is pancake with active core diameter is 200 cm and active core height is 165 cm.

CALCULATION METHOD AND CORE MODEL

The calculation has been conducted by using SRAC-CITATION code systems[9]. o perform burn-up calculations with the main parameters in Table 1. After that conducted the cell homogenization and collapsing 74 groups energy into 8 groups, the results are stored in the user library. Reactor core calculation is then performed, by first calling the user library to the SRAC-CITATION environment. The calculations will be repeated, if the convergence has not been reached. Power level results of SRAC-CITATION calculations are used as input for the calculation of the fuel cell. After that if convergence is reached, check whether radial Peaking Factor (PF) has been obtained in accordance with the required standards. If the value is not appropriate then the calculation is repeated by firstly adjusting the width of the inner, middle, and outer core. The calculations are complete when the desired PF value was obtained.

4th International Conference on Advances in Nuclear Science and Engineering (ICANSE 2013)
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TABLE 1. Sample design parameter

Paremeter	Value/Description	
	Reference/Core O	**Core M (multi radial region)**
Power (MWt)	350	
Number of equal volume region	10	
Fuel Material	U-10wt%Zr	
Cladding Material	Stailes Steel	
Coolant Material	Helium	
Fuel Volume fraction	65%	62.5/64/67.5%
Cladding Volume fraction	10%	10%
Coolant Volume fraction	25%	22.5 – 27.5%
Active core diameter (cm)	200	
Active core height (cm)	165	
Reflector radial/axial width (cm)	50	
Pin pitch (cm)	1.4	
Sub cycle length (years)	10	
Reactor life (years)	100	

This design adopted modified CANDLE type B (MCANDLE-B) that described in Figure 1.

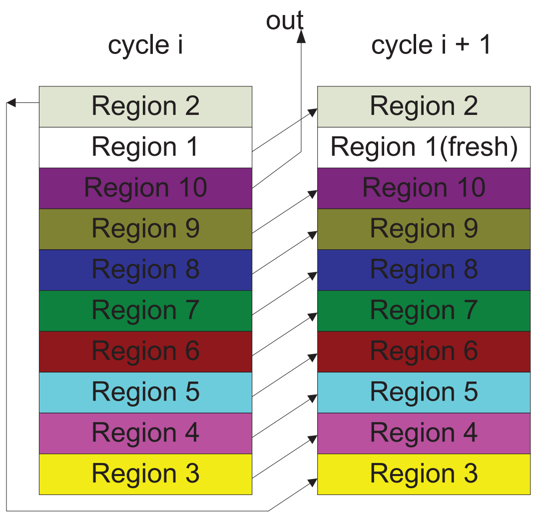


FIGURE 1. Modified CANDLE type B burnup scheme and its shuffling strategy.

RESULTS AND DISCUSSIONS

In this study we investigate and compare the results of original core or reference core (Core O) and reduced power peaking factor core by radial region division into 3 regions (Core M). Figure 2 shows comparison of the effective multiplication factor change with burn-up for Core O (reference core) and the Core M(reduced power peaking core). The k_{eff} value at the beginning of cycle (BOC) of the core M is about 1.00083 (see Table 2). It is monotonically continue to increase until the end of cycle (EOC). Its mean this reactor can be operated for 10 years without refuelling. The difference value of the effective multiplication factor of core O and core M are significant that beginn at the beginning of the cycle and continue to grow until the end of the cycle. The core M has in general lower k-eff value compared to that of reference core due to the setting of lower fuel volume fraction in the central region for power peaking reduction strategy.

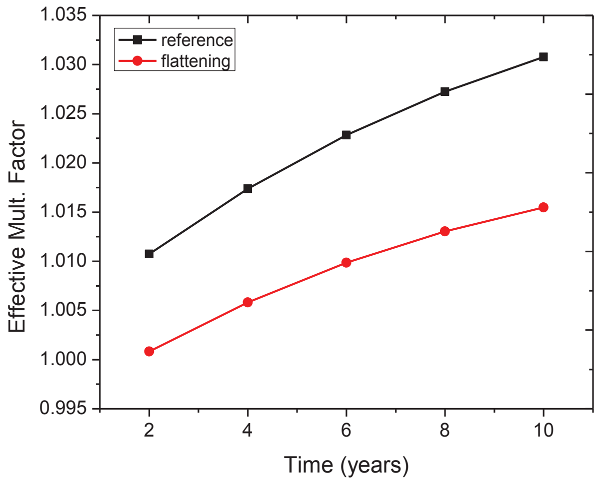


FIGURE 2. The Effective multiplication factor, k_{eff}, change during burn-up in one sub cycle.

TABLE 2. Comparison of calculation results between the reference and flattening core.

Column Header Goes Here	Reference core(Core O)	Core M
k_{eff} at BOC	1.01075	1.00083
Average power density (Watt/cc)	87.137	82.267
Maximum power density(Watt/cc)	351.00	282.20
Power peaking factor	4.03	3.43

Figure 3 shows the radial power distribution of the core O and the core M. Radial direction of the reactor core is divided into 3 regions, namely inner, middle and outer core with the size of 20 cm, 15 cm and 65 cm respectively. Mesh number 1-4 associated with the inner core, mesh number 5-7 associated with the middle core, mesh numbers 8-20 associated with outer core, and mesh numbers 21-30 are reflector. Power distribution profile of the core M is better than that of original core as can be seen from Figure 3. The value power peaking factor can be reduced from about 4 to about 3.4.

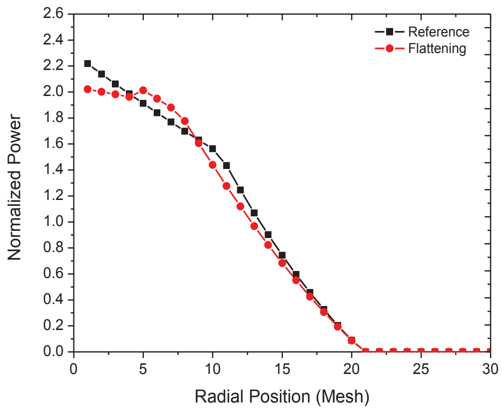


FIGURE 3. Radial power distribution of reference core and flattening core.

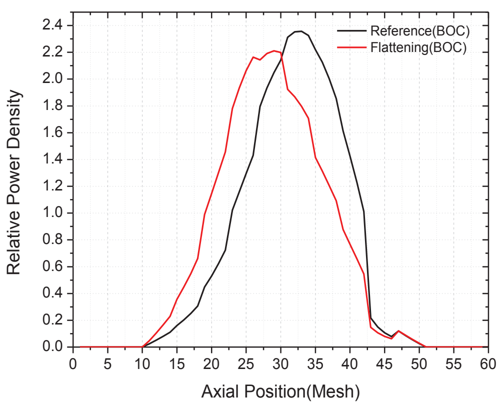
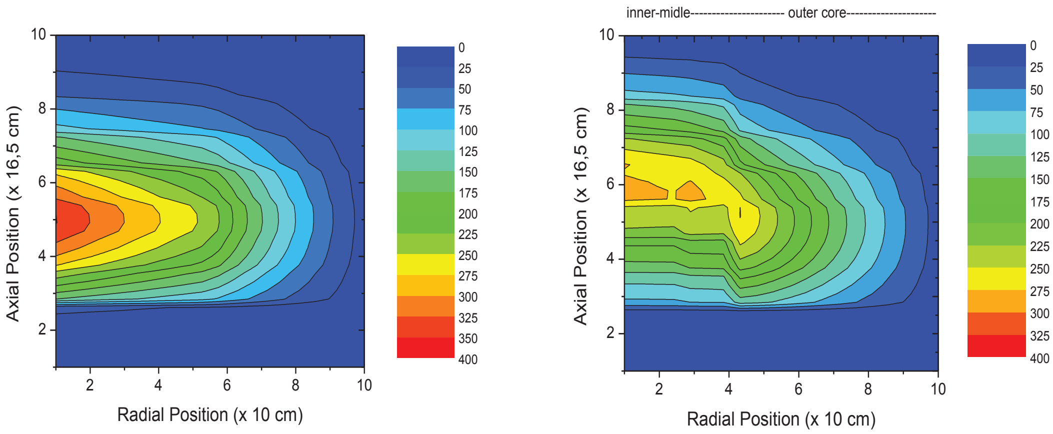


FIGURE 4. Relative power density axial distribution at the BOC.

Figure 4 shows the power density axial distribution and its change during 10 years of burn-up at the beginning of cycle. It is shown that maximum power distribution for the core M is slightly lower than that of core O.

Figure 5.a shows the profile of radial-axial power distribution for the reference core (core O); Reference core uses fuel volume fraction of 65%. Figure 5.b shows the profile of radial-axial power distribution of core M which uses fuel volume fraction 62.5%, 64% and 67.5% for the inner, middle and outer core respectively. The maximum power density values of the core M is 282.20 Watts/cc which is well below the maximum value of the reference core (351.00 Watts/cc). The profile of radial-axial power distribution of the core O and core M are shown in Fig. 5



(a) (b)

FIGURE 5. Power Density Distributions (a) before power flattening (b) After power flattening

CONCLUSIONS

In this research conceptual design study of long life 350 MWt GFR with natural uranium metallic fuel as fuel cycle input has been performed. Modified CANDLE burn-up strategy with first and second regions located near the last region (type B) has been applied. This reactor can be operated for 10 years without refuelling and fuel shuffling. Power peaking reduction is conducted by arranging the core radial direction into three regions with respectively uses fuel volume fraction 62.5%, 64% and 67.5%. The average power density in the modified core is about 82 Watt/cc and the power peaking factor decreased from 4.03 to 3.43.

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