Comparative Study on Various Geometrical Core Design of 300 MWth Gas Cooled Fast Reactor with UN-PuN Fuel Long-life without Refuelling

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Abstract. Nuclear power has progressive improvement in the operating performance of exiting reactors and ensuring economic competitiveness of nuclear electricity around the world. The GFR use gas coolant and fast neutron spectrum. This research use helium coolant which has low neutron moderation, chemical inert and single phase. Comparative study on various geometrical core design for modular GFR with UN-PuN fuel long life without refuelling has been done. The calculation use SRAC2006 code both PIJ calculation and CITATION calculation. The data libraries use JENDL 4.0. The variation of fuel fraction is 40% until 65%. In this research, we varied the geometry of core reactor to find the optimum geometry design. The variation of the geometry design is balance cylinder; it means that the diameter active core (D) same with height active core (H). Second, pancake cylinder (D>H) and third, tall cylinder (D<H). The reflector radial-axial width is 50 cm. The power is 300 MWth. First calculation, we calculate survey parameter for UN-PuN fuel with fissile contain from Plutonium waste LWR for each geometry. The minimum power density is around 72 Watt/cc, and maximum power density 114 Watt/cc. After we calculate with various geometry core, when we use the balance geometry, the k-eff value flattest and more stable than the others.

1. Introduction

The ten countries have joined together to form the Generation IV International Forum (GIF) to develop future generation nuclear energy system. It need to provide manageable nuclear waste, effective fuel utilization, competitive economics, recognized safety performance and secure nuclear energy systems and nuclear materials [1].

One type of Generation IV reactor is Gas Cooled Fast Reactor (GFR). The GFR system features a fast-spectrum helium-cooled reactor and closed fuel cycle. The fast spectrum makes it possible to utilize available fissile and fertile materials two orders of magnitude more efficiently than thermal spectrum gas reactor with once-through fuel cycles [2]. Comparative study on various geometrical core designs of 300 MWth Gas Cooled Fast Reactor with UN-PuN fuel has been done. The neutronic analysis of GFR with three geometry type, i.e. pancake cylinder, balance cylinder and tall cylinder has been done with SRAC2006 code calculation. Beforehand, analysis neutronic of GFR with SRAC2006 code system with modified CANDLE burn up scheme has been analysed [3-8]. The neutronic analysis for long-life 200MWth GFR also has been analysed [9]. In this research, the neutronic calculation calculate in order to the reactor can be operate long-life without refuelling for the fuel.

2. Design Concept and Calculation Methods

Table 1 shows parameter design of fuel pin and specification of reactor core. It use nitride fuel (UN-PuN) fuel which is the plutonium obtained from waste fuel from Light Water Reactor (LWR), so it can reduce the amount of plutonium in the world.

Table 1. Parameter design of fuel pin and specification of reactor core

Parameter	Specification
Power	300 MWth
Fuel material	UN-PuN
Cladding material	Silicon Carbide (SiC)
Coolant material	Helium
Fuel volume fraction	40%-60%
Cladding volume fraction	10%
Coolant volume fraction	30%-50%
Pin pitch	1.45 cm
Reactor core type	• Pancake cylinder (D>H) • Balance cylinder (D=H) • Tall cylinder (D<H)
Volume core	• Pancake cylinder = 4190476.19 cm^2 • Balance cylinder = 4158289.14 cm^2 • Tall cylinder = 4106666.67 cm^2
Variation of fissile contain per region	8% : 10% : 12%

The fuel pin design geometry use hexagonal cell geometry which is presented in **Figure 1**. The fuel pin is arranged into heterogeneous core configuration with three variation fuel (Fuel 1, Fuel 2 and Fuel 3). The variation of fissile contain per region show in Table 1, F1=8%, F2=10%, and F3=12%.

There are three reactor core geometry designs has been calculated (see **Figure 2**). The dimension (width and height) of the cylinder is show in **Table 2**.

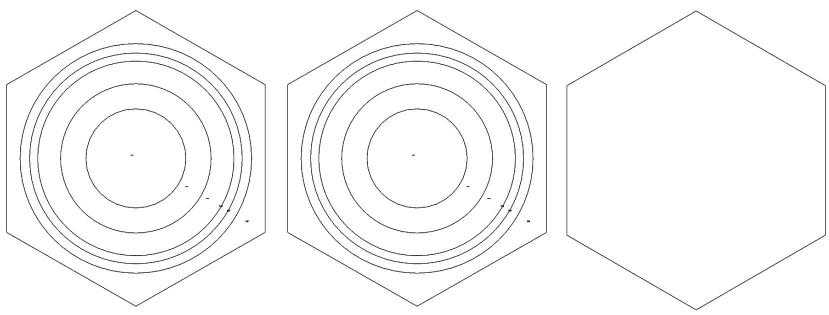

Figure 1. Fuel pin hexagonal geometry design (output result of PIJ Calculation)

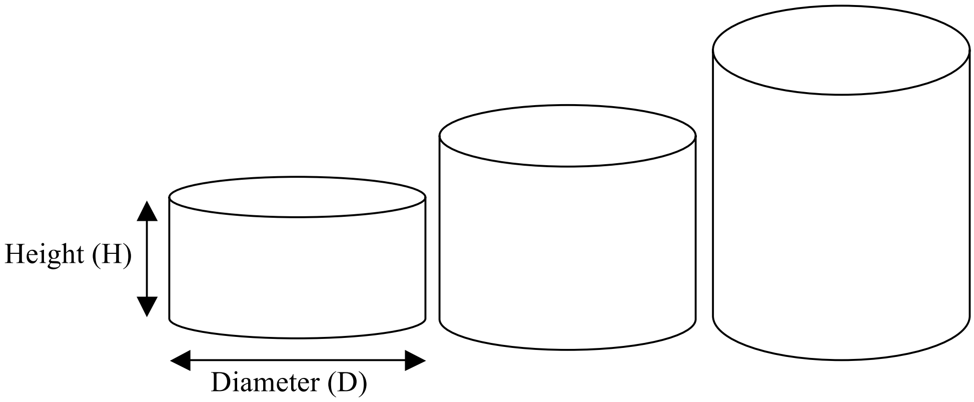

Figure 2. Scheme of various core geometry design (pancake cylinder, balance cylinder and tall cylinder)

Table 2. Various core geometry design of the reactor

Type of Geometry Core	Width active core	Height active core
Pancake cylinder	200 cm	100 cm
Balance cylinder	159 cm	159 cm
Tall cylinder	140 cm	140 cm

The neutronic analysis use SRAC2006 code system which is developed by JAERI (now JAEA) to calculate the neutronic analysis of the reactors. And the data libraries use JENDL 4.0[10].

3. Results and Discussion

Figure 3 shows effective multiplication factor (k-eff) value of gas cooled fast reactor with various core geometry design. For all core geometry design, they can be operated plus than 20 years. For all geometry have same trend of the k-eff graph. The balance cylinder has k-eff value flattest than the other. It means when we use balance cylinder, the k-eff value is more stable than the other. The maximum k-eff value of balance cylinder is 1.0088.

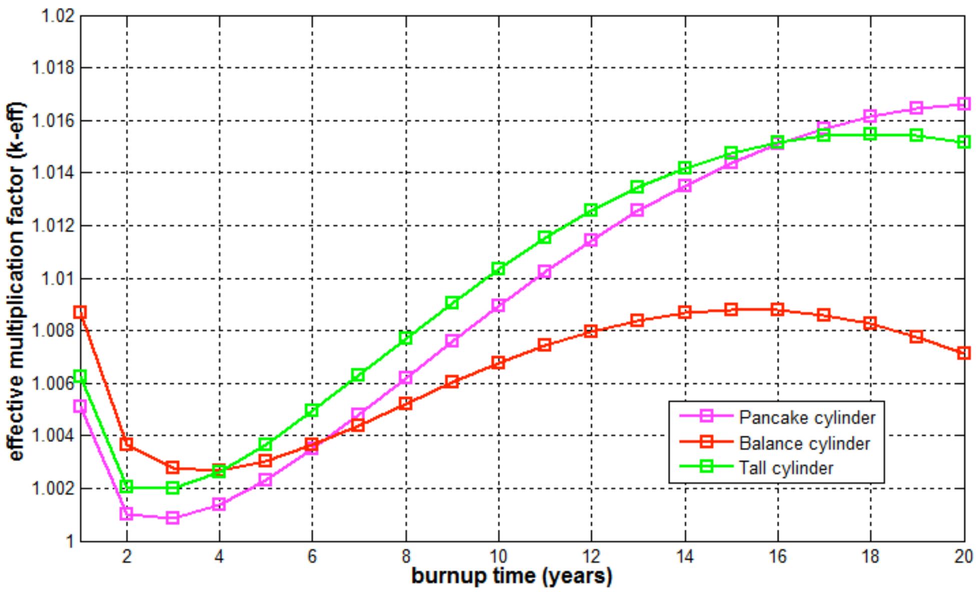

Figure 3. Effective multiplication factor (k-eff) value of gas cooled fast reactor with various core geometry design

Table 3 show the parameter and power density results of the reactor. From the table pancake cylinder has power density value greatest than the others. In this case, due to it has fuel volume fraction the greatest one. The balance and tall cylinder has average power density almost the same.

Table 3. The parameter and power density results of the reactor

Type of geometry	Volume fraction (%)			Power density (Watt/cc)	
	Fuel	Cladding	Coolant	Average	Peak
Pancake cylinder	54.5	10	35.5	66.35	114
Balance cylinder	46	10	44	51.34	75
Tall cylinder	49.5	10	40.5	51.73	72

Figure 4 show excess reactivity value of gas cooled fast reactor with various core geometry design. From **Figure 4** all geometry has excess reactivity value less than 1.8%, means that the reactor is stable. For balance cylinder has excess reactivity value less than 1%. The maximum excess reactivity value is 0.87%.

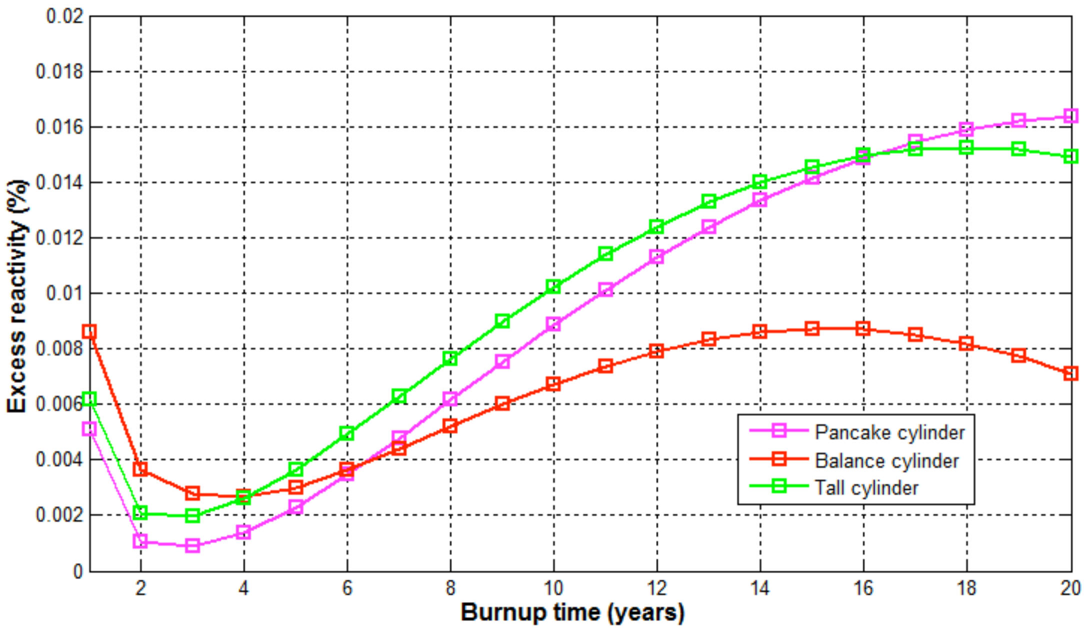

Figure 4. Excess reactivity value of gas cooled fast reactor with various core geometry design

4. Conclusion

Comparative study on various geometrical core designs of 300 MWth Gas Cooled Fast Reactor with UN-PuN fuel has been done. For all core geometry design (balance, pancake, tall cylinder) can be operated more than 20 years without refueling. It has same trend of graph in k-eff value and excess reactivity value. The maximum k-eff value is 1.0088 and the maximum excess reactivity value 0.87%. This design is more stable than the others.

Acknowledgment

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References

[1] GIF (The Generation IV International Forum) 2002 *A technology Roadmap for Generation IV Nuclear Energy System* (U.S DOE Nuclear Energy Research Advisory Committee) p 1-22
[2] GIF (The Generation IV International Forum) 2009 *GIF R&D Outlook for Generation IV Nuclear Energy System* (the OECD Nuclear Energy Agency) p 6
[3] Fiber M Zaki S Abdul W Khairul B Menik A and Hiroshi S 2013 *Advanced Material Research* **772** 501
[4] Zaki S and Hiroshi S 2013 *Annals of Nuclear Energy* **54** 58
[5] Menik A Zaki S Fiber M Abdul W Khairurrijal Idam A Aziz F and Hiroshi S 2013 *Applied Mechanics and Materials* **261-262** 307
[6] Fiber M Menik A Zaki S Abdul W Khairul B Ferhat A Sidik P and Hiroshi S 2014 *AIP Conference Proceedings* **1584** 105
[7] Fiber M Zaki S Abdul W Khairul B Menik A and Hiroshi S 2014 *AIP Conference Proceedings* **1615** 47
[8] R.D. Syarifah, Z. Su'ud, K. Basar and D. Irwanto, 2016 *J. Phys.: Conf. Ser.* **776** 012103
[9] R.D. Syarifah, Y. Yulianto, Z. Su'ud, K. Basar and D. Irwanto, 2016 *Matec Web Conf.* **82** 03008
[10] Okumura K 2002 *SRAC version 2002* (Japan Atomic Energy Research Institute) p 1-28