Comparative study on various thermal power for gas cooled fast reactor with uranium plutonium nitride fuel

Cite as: AIP Conference Proceedings **2278**, 020040 (2020); https://doi.org/10.1063/5.0015438
Published Online: 26 October 2020

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Comparative study on Various Thermal Power for Gas Cooled Fast Reactor with Uranium Plutonium Nitride Fuel

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Abstract. Comparative study on various thermal powers for gas cooled fast reactor with uranium plutonium nitride fuel has been done. The purpose of this study was to compare various thermal powers on nuclear power plant (NPP) Gas Cooled Reactor type. Neutronics calculation was design by using SRAC Code version 2006 (Standard Reactor Analysis Code) with the data nuclides from JENDL-4.0 under the Linux Operating System with nuclear data library JENDL4.0. Neutronic calculations were done through some parameter surveys to obtain the optimal results. The first step was calculation of fuel cell (PIJ-method) by using hexagonal cell and then followed by calculation of core reactor (CITATION-method). The power variations carried out are seven variations of power, namely from 100 MWth to 700 MWth. In this power variation all parameters are made the same. The parameters that are made are the same, namely the percentage of plutonium, the volume fraction of the fuel, the reactor geometry type, the diameter and the active core height (terrace). All power variations have an average power density value and maximum power density increases along with the increase in thermal power. When thermal power increases, the k-eff peak value will be increase too. It shows that if the thermal power increases, the burn-up fuel is also increase more than before, so that the fuel is used for the burn-up process which causes k-eff increase. The increasing graph which shows in the figure explains that the reactor breeding occurs, while the declining graph shows the reactor is burning.

INTRODUCTION

The world demand for electricity is again increasing and with it the need of new generation facilities [1]. Nuclear Power Plant (NPP) is one of alternative energy to replace the fossil fuel. NPP does not produce carbon dioxide (CO2) as a residue. In 2007, the International Atomic Energy Agency reported there were 439 nuclear power reactors in operation in the world, operating in 31 countries [1]. In this research, the comparative study is about Gas Cooled Fast Reactor (GFR), one of Generation-IV reactor type [2-3]. GFR use high energy neutron to change the natural uranium as fissile material in chain burn-up. There are some research has been done before about neutronic analysis, geometrical design, fuel comparison, and minor actinide [4-11]. In this study, we will compare the thermal power of Gas Cooled Reactor long-life use uranium plutonium nitride (UN-PuN).

Climate Change and Sustainability Engineering in ASEAN 2019
AIP Conf. Proc. 2278, 020040-1–020040-5; https://doi.org/10.1063/5.0015438
Published by AIP Publishing. 978-0-7354-4008-1/$30.00

DESIGN CONCEPT AND CALCULATION METHODS

The fuel use uranium plutonium nitride (UN-PuN) fuel, the cladding use silicon carbide (SiC), and the coolant use gas, i.e. helium. Core geometry design used cylinder pancake with height active core 100 cm, diameter active core 240 cm and reflector 50 cm. The type of fuel pin is hexagonal fuel pin cell (Figure 1). Table 1 shows the parameter design of fuel pin.

TABLE 1. Parameter designs of fuel pin

Parameter	Specification
Pin pitch	1.45 cm
Minor actinide	Am-241, Np-237
Burnable poison	Pa-231
Percentage Plutonium	5 % – 15 %
Percentage Americium	0% - 5%
Percentage Neptunium-237	0% - 5%
Percentage Protactinium	0% - 5%
Power	100 – 700 MWth
Burn-up time	>20 year
Pin pitch/diameter	1.45 cm

The hexagonal cell geometry is divided into three type regions, the fuel regions, the cladding regions and the last is coolant regions. The hexagonal cell and the regions can be seen in Figure 1.

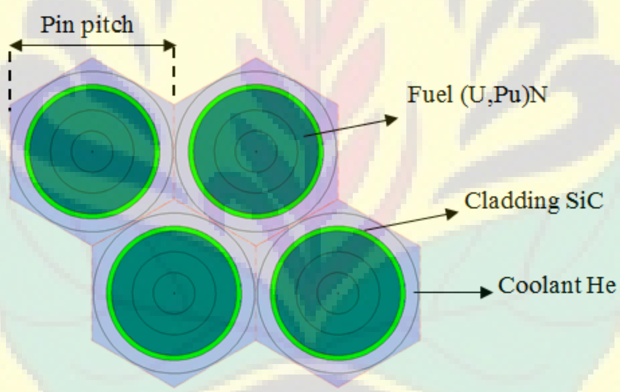

FIGURE 1. Hexagonal geometries fuel pin in core reactor

After calculated fuel pin calculation with hexagonal fuel pin cell, we calculate core reactor with three variation fuel. The variation fuel is F1 is in the center, F2 in the middle and F3 in periphery, and after that there is a reflector. The percentage of plutonium in F1:F2:F3 = 8%:10%:12%. It means, in the fuel 1 (F1), the fuel combine of plutonium from spent fuel 8% and 92% from natural uranium.

Standard Reactor Analysis Code (SRAC) ver. 2006 is special code which has been used to calculate the neutronics analysis, both thermal and fast reactor. The calculation method use SRAC 2006 and libraries JENDL 4.0. The fuel pin cell calculation used PIJ calculation and core reactor calculation used CITATION calculation [12].

RESULTS AND DISCUSSIONS

Before we calculated the comparation of thermal power in GFR 300MWth, we take the calculation from the research before, the optimization of design 300 MWth GFR which has been show in the Table 2. The percentage of plutonium from each fuel is Fuel 1 (F1) 8%, Fuel 2 (F2) 10% and Fuel 3 (F3) 12%. The plutonium is taken from spent fuel of PWR (Pressurized Water Reactor) which has been used 33MWd/ton. The plutonium has been cooled down 1.5 years. The fuel is also has been added by minor actinide. Americium (Am), Neptunium (Np) and

Protactinium (Pa) are the minor actinide which has been added. When the minor actinide added in the fuel, it can reduce the amount of minor actinide in the world. Minor actinide has high toxicity. In this research, we can reduce the amount of minor actinide by add it in the reactor. The minor actinide also can reduce the value of factor multiplication factor in the gas cooled fast reactor [4].

TABLE 2. Optimization results of GFR 300 MWth with UN-PuN fuel

Parameter	Optimization results
Percentage of plutonium in F1	8%
Percentage of plutonium in F2	10%
Percentage of plutonium in F3	12%
cooling down time	1,5 year
Geometry design	cylinder *pancake*
Percentage of addition of Am	0,3%
Percentage of addition of Np-237	0,3%
Percentage of addition of Pa-231	4,5%
Fuel volume fraction in F1	57,5%
Fuel volume fraction in F2	60%
Fuel volume fraction in F3	60%
Coolant volume fraction in F1	32,5%
Coolant volume fraction in F2	30%
Coolant volume fraction in F3	30%

The fuel and coolant volume fraction for each type of fuel is varied. The variation used to give the precision value of multiplication factor. The multiplication factor is used to knowing the stability of the reactor. After that, we varied the thermal power. There are seven thermal power variations, i.e. 100MWth, 200MWth, 300MWth, 400MWth, 500MWth, 600MWth and 700MWth. All parameters are made the same, except thermal power variation. The parameters are the percentage of plutonium, fuel volume fraction, reactor geometry type, diameter active core and height active core. Table 3 shows the average power density and maximum power density values for each power variation. All thermal power variations have an average power density value and maximum power density value. From the table we can know that when the thermal power is increase, the average and the max power density also increase because when the thermal power increase, the burn up of the reactor is increase. So, it can make average and power density increase too.

TABLE 3. Average power density and maximum power density value of various thermal power

No.	Thermal Power (MWth)	Average power density (Watt/cc)	Max power density (Watt/cc)
1.	100	22,10	31,55
2.	200	44,21	63,10
3.	300	66,31	94,66
4.	400	88,41	126,21
5.	500	110,52	157,22
6.	600	132,62	189,32
7.	700	154,73	220,88

When thermal power rises, the k-eff value (peak value) increases and the burn-up of the fuel increases than before. Figure 2 shows the effective multiplication factor (k-eff) of several thermal powers. The increasing graph in Figure 2 shows that the reactor is breeding, it means that the fertile material (in here is uranium 238) absorb the neutron and become fissile material (in here are plutonium 239 and plutonium 241). Whereas the declining graph in the Figure 2 shows the reactor in a burning. It means that many fissile materials in the reactor do a fission reaction. Figure 3 shows burn up level value of various thermal powers. Thermal power rises with the burn-up level. This means that the energy consumed from the reactor is consistent with its thermal power.

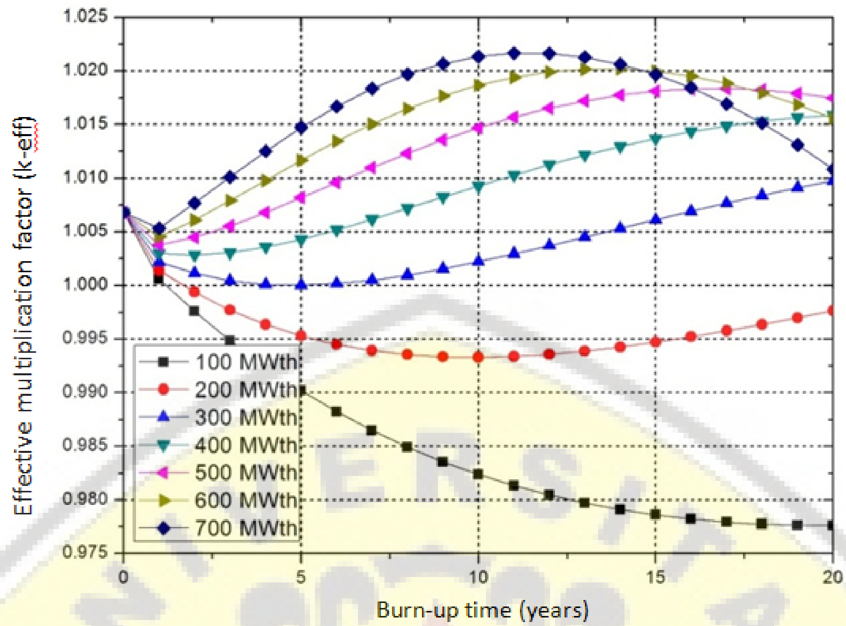

FIGURE 2. The effective multiplication factor (k-eff) of several thermal powers

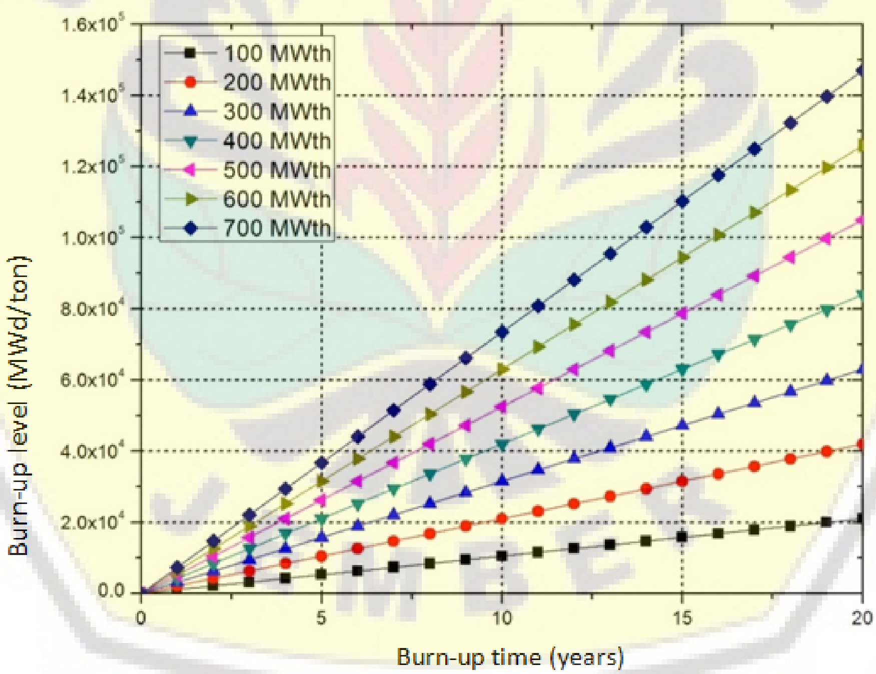

FIGURE 3. Burn up level value of various thermal powers

CONCLUSION

Comparative study on various thermal powers for gas cooled fast reactor with uranium plutonium nitride fuel has been done. The power variations are from 100 MWth up to 700 MWth. All power variations have an average power density value and maximum power density increases along with the increase in thermal power. When thermal power increases, the k-eff peak value will be increase too. It shows that if the thermal power increases, the burn-up fuel is also increase too.

ACKNOWLEDGMENTS

This work was supported by Hibah Kelompok Riset (KeRis) Komputasi Material Terapan, University of Jember which is gratefully acknowledged.

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