The preliminary design of GFMR with UC fuel

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1. Introduction

The GFR (Gas-Cooled Fast Reactor) is one of six advanced reactor concepts selected by the Generation-IV International Forum (GIF) that have the potential to improve safety, sustainability, affordability, and nonproliferation [1]. The GFR utilizes helium as the primary coolant and uses ceramic fuel and structural materials to enable high efficiency and high temperature operation. These features are advantageous for hydrogen production and other process heat applications. Designing an MMR-sized reactor requires the use of highly efficient fuel in a limited size. In this paper, 60% U235 is selected as the nuclear fuel ratio considering long cycle operation. Generally, GFRs consider highly enriched uranium, plutonium, or thorium. Various fuel forms have been tried for GFRs, including coated particle fuels, silicon carbide blocks, silicon carbide plates, and cylindrical fuel pins [2]. The purpose of this paper is to design a 4th-generation reactor GFR, with Micro Modular Reactor size call GFMR (Gas-Cooled Fast Micro Reactor), and to apply new fuels. The ceramic form of uranium carbide fuel is selected, and the power output is 10MWt. The objective of the core design was to create a compact gas-cooled fast reactor capable of producing high temperatures with a life cycle several times longer than that of a currently operating nuclear power plant. In this process, the SCALE 6.2 was used to design the core, and economic aspects such as the cost of materials and other parts of the reactor were not considered [3].

2. GFMR Design

The reactor core of this design has a power output of 10MWt. The number of hexagonal clusters is 17, with 84 fuel rods per cluster and 7 spaces for control rods and shutdown devices **(Table.1)**. The core has a fuel section 20 cm in the center and a fission gas plenum 5 cm above and below the fuel section **(Figure.1)**. The fuel and gas sections are completely covered with reflective Zr_3Si_2[4,5]. The nuclear fuel is UC, composed of 60% ^{235}U and 40% ^{238}U, with SS316 as the cladding material **(Figure.2)**. The high thermal conductivity of uranium carbide fuel enables efficient use of helium as a coolant, its high mechanical strength ensures durability and longevity; and its high chemical stability and high melting point make it suitable for nuclear reaction systems in high-temperature environments. The control rod and the stop rod are designed to wait on the top reflector through the follower so that they can be dropped at any time for control or emergency. The material of the control rod is B_4C with 90% ^{10}B.

Table I: Assembly parameters

Fuel Composition	UC (^{235}U 60%,^{238}U 40%)
Fuel Density	13.63 g/cc
Coolant	He
Reactor vessel	Zr_3Si_2
Core Height	50cm
Core Rad.	51cm
Rod diameter	0.5 cm
No. of rods	84
Clad type	SS316
Thermal Power	10MWth

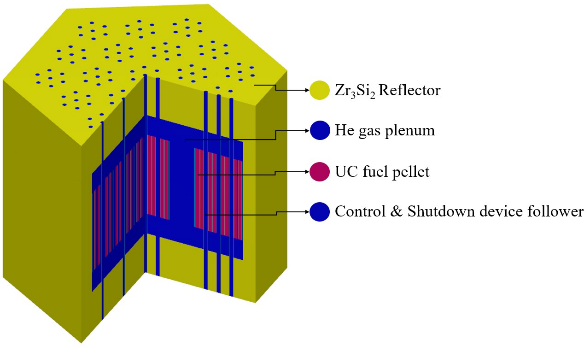

Fig.1 Cross sectional view of GFMR

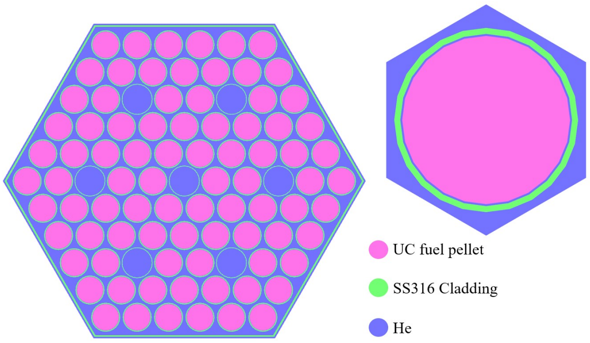

Fig.2 Assembly View

3. Methodology

In this paper, verify the performance of UC fuel and determine its suitability for GFR. The model is based on the three-dimensional core design code SCALE 6.2 code was used to independently derive the most important neutron parameters, determine control rod values, and perform fuel cycle and trace actinide burning studies. These calculations were based on the most recent ENDF/B-VII.1 cross section library in both standard 238 group structure and continuous energy [6]

4. Results

The effective multiplication factor was 1.10214 ± 0.0005, and the subcritical value was maintained at 0.92361 ± 0.0005 when the control rod was inserted. It showed a cycle of at least 27 years (Fig.3).

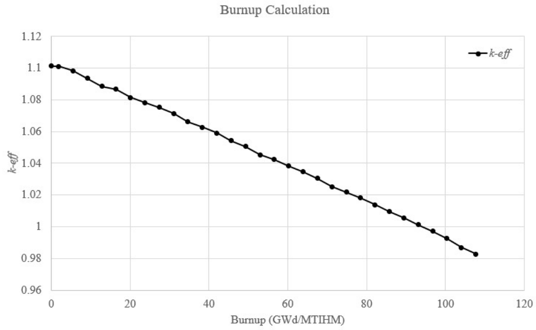

Fig.3 Burnup Calculation

The fast neutron flux in the center of the core increased to 1.54E+14 at the end of the cycle, and a neutron spectrum measurement by sampling neutrons revealed a prominence in the fast neutron region(0.5MeV<) **(Figure.4)**. The power distribution of the neutrons can also be seen in the figure. The figure is plotted as a linear contour, and while the power is higher in the center, there is no significant difference in units **(Figure.5)**.

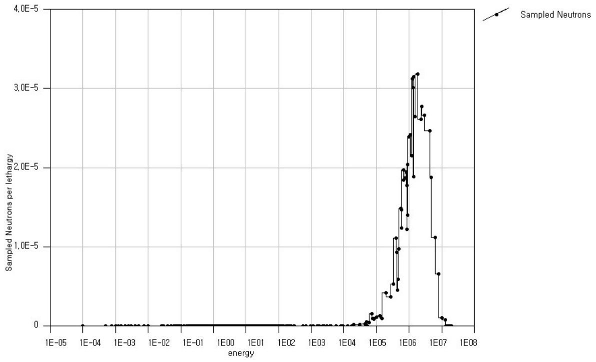

Fig.4 Neutron Spectrum (Lethargy)

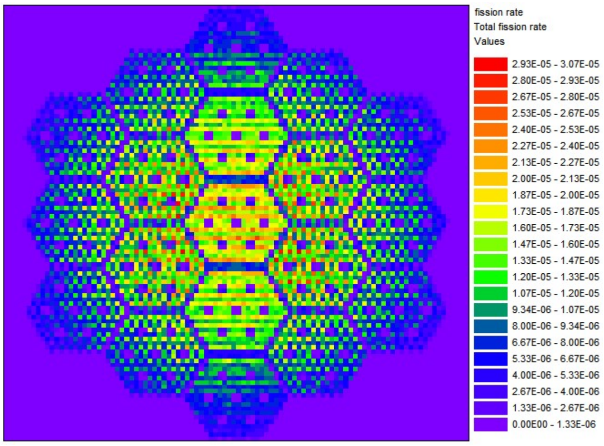

Fig.5 Total fission rate

5. Conclusion

Currently, fast reactors are researching world widely for commercialization. The purpose of this paper is to design a 4th-generation reactor GFR (Gas-cooled Reactor), with Micro Modular Reactor size call GFMR (Gas-cooled Micro Reactor), and to apply new fuels. Modeling and calculations were performed using the SCALE6.2 code for simulation. This paper implemented a GFR at the MMR level with an overall size of 50 cm and found that it can have a cycle time of 27 years using UC fuel. As it is a gas cooled fast reactor, it can produce high temperatures, and can be used for hydrogen production, seawater dehydration, etc. and more efficient heat utilization can be expected. As fast reactors operate at high temperatures, the materials such as cladding and reflectors, must have high heat resistance to withstand high temperatures, so future research will be conducted on material diversity.

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