Design of reactor physics experiments for Molten Salt Reactor in KUCA

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For the design of advanced reactors such as a Molten Salt Reactor, it is necessary to perform reactor physics experiments for code validation, etc. In this research, reactor physics experiments for the Kyoto University Critical Assembly (KUCA) are designed in support of Molten Salt Reactor research and development. The ERANOS software is used to evaluate the properties of the experiments in the KUCA core.

Keywords: Molten Salt Reactor, KUCA, reactor physics experiment, numerical analysis

1. Introduction: Several research organizations, both academic and commercial, are performing research into the so-called Molten Salt Reactor (MSR) as an innovative nuclear reactor for future power production. In our research, the focus is on a chloride molten salt reactor that is a 600MW thermal, fast-spectrum reactor with a uranium-plutonium fuel operating at a temperature of some 550°C. The current research targets to use the Kyoto University Critical Assembly (KUCA) to its maximum potential to support experiments on chloride-fueled MSR research and development.

2. Experimental design and results: The LEU fuel was selected to use in KUCA dry core is 19.75 wt% U7Mo-Al dispersion fuel. The dimensions of the LEU plate are 50.8 x 50.8 x 2.40 mm with the thickness of the U7Mo foil is 1.45 mm [1]. To create a material composition similar to MSR, AlCl3 and NaCl plates with suitable dimensions were selected to combine with the LEU fuel plate to form a unit fuel cell called MSR fuel cell (see Fig. 1.). Beryllium (Be), and graphite (Gr) were used as the reflector. The core configurations have been calculated by the ERANOS code using a two-dimensional cylindrical model. Some survey calculations showed that the core uses only MSR fuel cells was not sufficient to achieve criticality in KUCA. Therefore, the solution is to design a core with two zones, an inner zone consists of MSR fuel cells and an outer zone which uses fuel cells with only the LEU fuel plate. The core configuration with the dimension of 9 x 9 fuel assembly and 85.3 cm high use Be and Gr as the reflector was selected to calculate. The dimensions of MSR fuel zone are 5 x 5 fuel assembly and 22.3 cm in height. The results showed that this core configuration can achieve criticality with k_{eff} = 1.00405. The representativity factor is defined by:

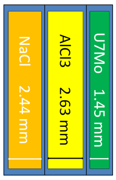

Figure 1. Unit cell.

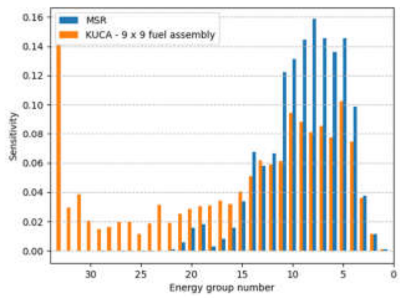

Figure 2. The sensitivity coefficients of k_{eff}

$$r = \frac{s_R^T D s_E}{\sqrt{s_R^T D s_R}\sqrt{s_E^T D s_E}} \quad (1)$$

For the proposed core in KUCA, $r = 0.428$ which is acceptable. The sensitivity coefficients are shown in Fig. 2.

3. Conclusion: We designed a core configuration that can be achieved in KUCA to support researching MSR. The results showed that the configuration with the dimension 9 x 9 fuel assembly and 85.3 cm high can be used for the experiment. However, further research is needed to determine if this configuration can operate safely at KUCA.

References

[1] Morman, J. et al., “History and Current status of the KUCA Dry Core Conversion Project” RERTR-2019 International Meeting, Oct. 6-9, 2019, Zagreb, Croatia.