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Nuclear Design Concepts of Research Reactor for the Developing Countries

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1. Introduction

As a part of developing a new research reactor, the preliminary conceptual design has been carried out. The research reactors are nuclear facilities that organized around a neutron source and dedicated to fundamental and applied research. A research reactor may have multi goals. Of these, however, to have the high flux is almost a common goal. It objects the isotope production for several field area, material test etc. Since high flux application is too wide, developing countries may wish to have High Flux Research Reactor (HFRR) such as FRMM-II reactor, ATR, JHR, HANARO, OPRAL and so on that were proposed based on several design concepts. In order to obtain high neutron flux, the core is generally needed to be compact as much as possible but it also depends on the fuel density (or enrichment), fuel type, fuel cycle, cooling system design and so on. In this study, it was aimed to design a new HFRR with simplifications as preliminary state. [1-4]

2. Nuclear Design Concepts

2.1 Some Basic Design Parameters

Some basic design parameters of proposed design are described in Table 1.

Parameter	HFRR
Power	10 MWth
Pressure	2 atm
Rx type	Tank pool
Fuel	U_3Si_2-Al (19.95% U235)
Fuel type	Tubular type, (1x8) , (1x3)
Fuel cladding	Al-Fe-Ni alloy
Active fuel length	50 cm
# of assemblies	25
Assembly array in core	Rectangular array
Control rod material	B_4C
Control rod cladding	Zircaloy
Moderator matrix	Al or graphite
Moderator dimension	60 cm x 60 cm x70 cm
Coolant	H_2O, upward force convention
Reflector	D_2O
Flux level	>1E+14 n/cm^2-s (core)
Cycle length	1 month

Table 1. Some basic design parameters

2.2 Assembly Design

Figure 1(a) is only one (1x3) fuel assembly in core and its central part is used as irradiation hole. Hence it is named as Assembly with Irradiation Hole (AIH). The other fuel assemblies are (1x8) that can be hosted by moderator filler or control rod. Figure 1(b) is Assembly with Moderator Filler (AMF) whereas Fig. 1(c) is Assembly with Control Rod (ACR). There are no stiffeners for simplicity. Assemblies are embedded into the moderator matrix that may be either aluminium or graphite. Therefore, three different compositions of assemblies can be seen in core-wise.

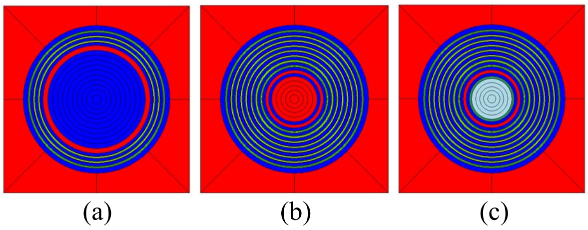

Fig. 1 Assembly compositions

2.3 Assembly Calculation Methodology

It was evaluated the flux levels in assemblies in detail using HELIOS whether it is reasonable or not. Three assembly compositions and two moderator matrixes give six combinations of assembly calculations that for:

- AIH in Al matrix or graphite matrix
- AMF in Al matrix or graphite matrix
- ACR in Al matrix or graphite matrix

In those calculations, central part of each assembly is subdivided into some rings to calculate detail fluxes. Flux level at those rings and fuel meats were evaluated. Serially from innermost ring to outermost fuel ring, those are labeled by C1, C2, …C10 and F1, …F3 for AIH whereas C1, C2, …C5 and F1, F2, …F8 for both AMF and ACR. Therefore totally thirteen rings are considered to evaluate flux level in an assembly.
The neutron groups are considered as two-group and thermal energy range is 0→0.625 eV. No sectors in each ring and hence each ring has single flux value. Geometrical buckling is taken into account in calculations.

3. Results in Assembly Calculations

As shown in figures (2), (3) and (4), the thermal flux levels in assemblies are reasonable and consistent with the expected ones. Moderator filler is used for interior moderation and it rises up flat flux in the central part.

Control rod controls the excess reactivity and it can also give flat flux in the central part. Furthermore, it was found that aluminium and graphite are almost the same for moderation.

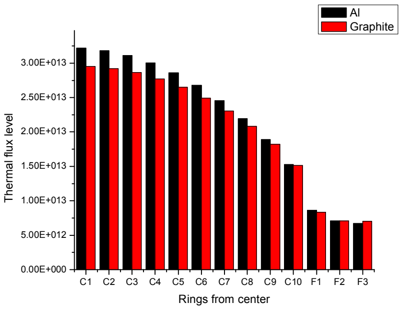

Fig 2 Thermal flux level in AIH

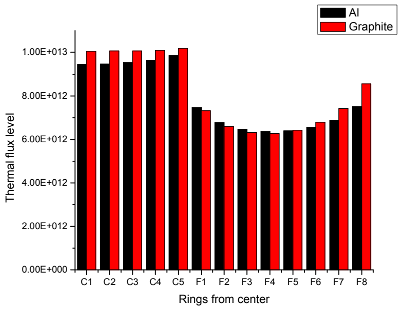

Fig 3 Thermal flux level in AMF

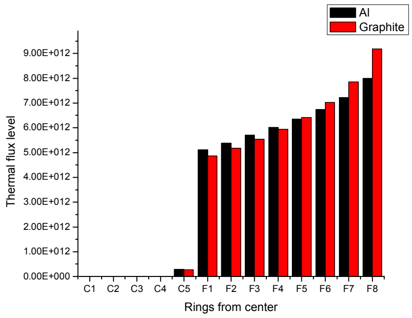

Fig 4 Thermal flux level in ACR

4. Core Design of New HFRR

In this proposed core design, as shown in Fig 5, AIH was located in core center, four ACRs are at corner and twenty AMFs are in remaining core region. Core is square and moderator matrix is surrounded by 1 cm of thin water layer for matrix cooling. Reactor vessel is made up of Stainless Steel 304 with thickness of 1 cm as gamma shielding and 30 cm thick of heavy water outside the vessel reflects neutrons back into the core and maintain the nuclear reaction. Thermal flux distribution and flux level can be seen in Fig 6. At core center, there is an enough flux level for existence of irradiation bole. The proposed design is simplest one of HFRR and it is aimed to expand for other design goals as much as possible as future work.

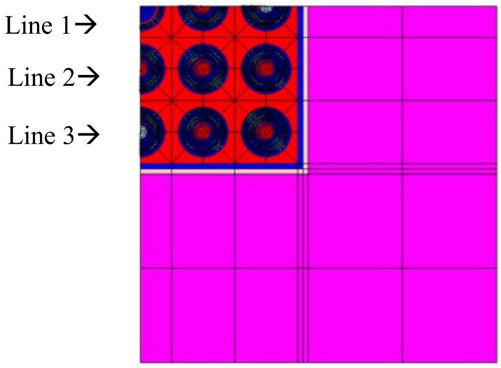

Fig 5 Conceptual quadrant core design

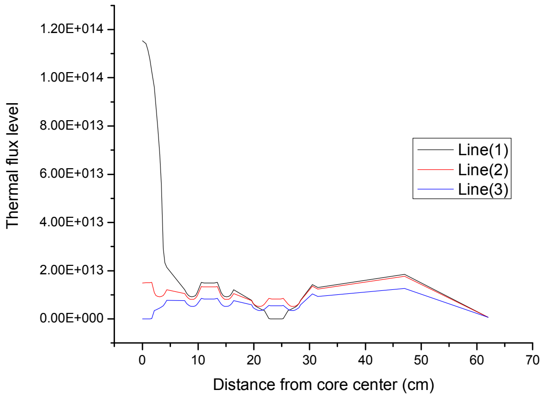

Fig 6 Thermal flux distribution in HFRR

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