PRESENT STATUS OF NEXT TERM PROJECT IN KURRI

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Abstract

A final goal of the next term project in Kyoto University Research Reactor Institute (KURRI) is to establish a new neutron source of accelerator driven subcritical reactor (ADSR) as a substitute for the current research reactor KUR. A ring cyclotron has become a main candidate of an accelerator system. A conceptual design study has been carried out to examine the nuclear features of a research reactor type ADSR. In addition, a basic experimental study on the ADSR was initiated by using the Kyoto University Critical Assembly (KUCA). From these studies, it became very clear that the nuclear characteristics of ADSR are essentially determined by the neutron multiplication process in the subcritical reactor.

1 INTRODUCTION

A final goal of the future plan in KURRI proposed in 1996 is to establish a new neutron source of ADSR as a substitute for the current research reactor KUR of 5 MW to promote the joint use program among Japanese universities [1]. Now, a ring cyclotron system has becomes a main candidate for this plan in consideration of the construction cost and the space in the KURRI site. The future plan can be divided into two phases. The first phase is the introduction of a 70 MeV ring cyclotron for the basic study on the ADSR, which will be carried out in combination with the KUCA. Based on the fruits of the first phase, the second phase will be the introduction of a 500 MeV ring cyclotron for the construction of the ADSR as a neutron source for the joint use program.

A conceptual design study has intensively been carried out to examine the nuclear features of research reactor type ADSR [2-6] by using the MCNPX code [7]. Moreover, a basic experimental study on the ADSR was also initiated formally in 2000 by using the KUCA, where a subcritical nuclear fuel assembly can be driven by 14 MeV neutrons generated from a Cockcroft-Walton type accelerator installed in the KUCA building.

2 PRESENT SITUATION

At the end of the last year, a scientific advisory committee of the Ministry of Education, Science, Sports and Culture (Monbusho) in Japan completed a report entitled "what the research reactor of university should be". This report mainly dealt with the KUR, since it is the largest among university reactors in Japan [6].

For the future of KURRI, this report concluded as follows: (1) It is reasonable to continue the operation of KUR for a while by reducing uranium enrichment of fuel. (2) It is advisable to promote the present study on the new neutron source by introducing a proper accelerator for the KUCA. (3) Since a considerable time is generally needed for the complete shut down procedure of nuclear reactor, it is desirable to initiate the preparation of this kind for the KUR with looking at the status in research from a medium- and long-term point of view. In conclusion, this report formally approved the first phase of the future plan to be adequate as a next term project in KURRI. However, the second phase is still open, since the High Intensity Proton Accelerator Project proposed jointly by the Japan Atomic Energy Research Institute (JAERI) and the High Energy Accelerator Research Organization (KEK) has already been initiated in Japan.

Table 1: Specification of 70 MeV Ring Cyclotron

Ion Source	
Type	Multicusp Ion Source
Maximum Current	10 mA
Extraction Energy	50 keV
RFQ	
Injection Energy	50 keV
Output Energy	400 keV
Operation Mode	CW
Average Beam Current	5 mA
Frequency	50 MHz
RF Power	100 kW
Total Length	2 m
Ring Cyclotron	
K Value	70
Injection Radius	0.31 m
Extraction Radius	3.42 m
Injection Energy	400 keV
Output Energy	70 MeV
Maximum Beam Current	2 mA
Number of Sectors	4
Magnet Weight	720 ton
Frequency	50 MHz
RF Power	200 kW

In response to this report, KURRI settled the following policies: (1) The operation of KUR will be continued for a while; the highly enriched uranium (HEU) fuel will be used until March 2006, and the low enriched uranium

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(LEU) fuel after April 2006. (2) The preparation will be initiated from now for the coming discontinuation of the KUR in the future. (3) Through the full equipment of the KUCA and the introduction of the 70 MeV ring cyclotron shown in Table 1, KURRI will promote the research including new topics. The basic study on the ADSR will be promoted by using neutrons with higher energy, and the new research will be initiated in the fields of medical treatment, material science and so on.

Then, KURRI provided a draft of budget for the fiscal year 2002 including the full equipment of KUCA and the introduction of the 70 MeV ring cyclotron. This draft was submitted to the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan. At the same time, KURRI began the negotiation in the framework of an agreement with the local public; it has successfully been completed in August 2001.

3 CONCEPTUAL DESIGN STUDY

By introducing the MCNPX code, a conceptual design study on the ADSR was carried out through the neutronics calculation under an assumption that the proton beam were incident upon a bulk target with a size of the current fuel element settled at the center of the KUR [2].

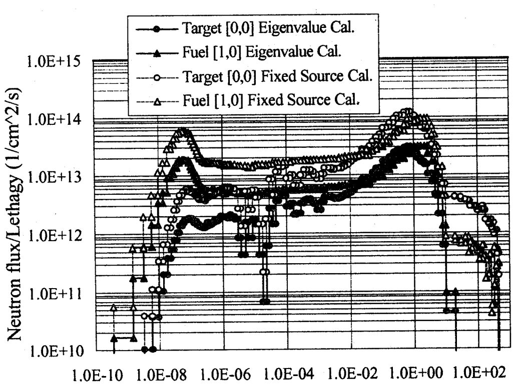

Figure 1: Comparison between spectra obtained by the eigenvalue and fixed source calculations.

The nuclear features of the research reactor type ADSR were examined by changing the design parameters systematically. For an example, the neutron spectra obtained by the eigenvalue and fixed source calculations are shown in Fig. 1. One can find that the main shape of neutron spectrum is very similar with each other because of the neutron multiplication process due to the fission chain reaction in the subcritical core, although the spallation neutrons can not be treated in the eigenvalue calculation. It was also found that the neutron flux level in the core becomes larger with increasing k_{eff} and incident proton energy, and the thermal power of the ADSR is expected to become higher than that in the KUR when the proton energy is selected to be 500 MeV. The target material has a certain impact on the neutron flux level depending on the properties of both the neutron production and absorption in material. The power distribution in the core does not strongly depend on either the subcriticality or the proton energy, and also on either the eigenvalue or the fixed source calculation. These results indicate that the eigenvalue calculation is still useful for the conceptual design of the ADSR.

The time-dependent behavior of neutrons after the proton pulse injection was examined to obtain an image of the reactor dynamics in the ADSR in relation with a pulse operation of the ADSR type neutron source [5,6]. This kind of behavior after the pulse injection of 14 MeV neutrons was also examined in relation with the KUCA experiments. Note that the effect of delayed neutrons can not be taken into account in the MCNPX calculation.

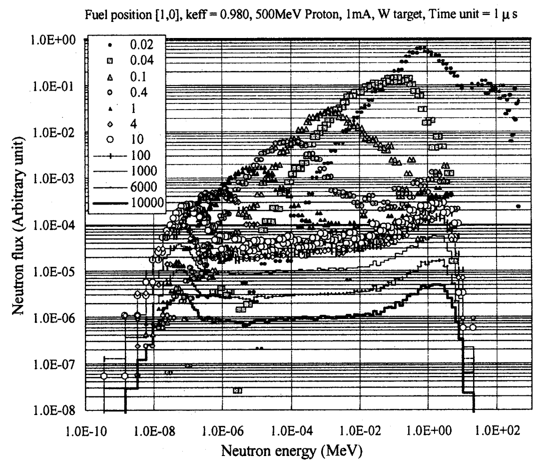

Figure 2: Evolution of neutron spectrum.

A typical result for the evolution of neutron spectrum after the proton pulse injection is shown in Fig. 2. This figure shows the following phenomena: (1) Neutrons with energy of more than 20 MeV decay out in a moment after the pulse injection. (2) Fast neutrons decay rapidly in the period of less than several μs. (3) The neutron spectrum approximately reaches an asymptotic one identical to that of the subcritical core at around 10 μs because of the neutron multiplication process in the ADSR. It was also found that no essential difference between the 500 MeV proton and the 14 MeV neutron injection in the time-dependent behavior of neutrons.

4 BASIC EXPERIMENTS

A series of basic experiments on the ADSR was formally initiated in 2000 by using the combination of a solid moderator core of the KUCA and a Cockcroft-Walton type accelerator [5,6,8]. A tritium target settled outside a polyethylene moderated/reflected core loaded with the HEU fuel was bombarded by a deuteron beam of around 200 keV to generate 14 MeV pulse neutrons as shown in Fig. 3.

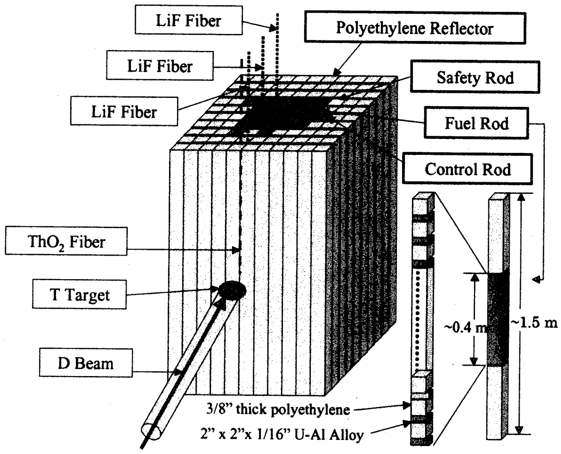

Figure 3: Image of the KUCA experiment.

Neutrons were detected by the optical fiber detector [9]; the ThO_2 detector was used to monitor 14 MeV neutrons, and the ^{6}Li enriched LiF detector to measure the neutron flux level in the core. To examine the dependence of the neutron multiplication and the neutron decay on k_{eff}, the subcriticality was systematically varied by adjusting the stroke of the control and safety rods inserted into the core. To measure the neutron flux distribution, the LiF detector was axially traversed along the fuel rod with a constant speed to facilitate the conversion from the time-dependent neutron counts to the reaction rate distribution. For the neutron decay measurement, the arc pulse of the accelerator was employed as a trigger signal to accumulate the data of time-dependent neutron counts after the pulse injection of 14 MeV neutrons.

The analysis of the KUCA experiment was executed by a continuous Monte Carlo code MVP [10] in combination with JENDL-3.2 [11]. The ^{235}U number density of fuel was reduced by about 5% in consideration of a bias observed in the criticality analysis of the HEU fuelled core [12]. It was found that the neutron multiplication is approximately expressed as a function of $1/(1-k_{eff})$ for the KUCA experiment. A large difference was observed between the measured and calculated behaviours in the neutron decay. However, this discrepancy can be explained in consideration that the MVP calculation can not take into account the effect of delayed neutrons:

5 CONCLUSIONS

The following conclusions can be derived:

(1) The nuclear features of the ADSR are practically determined by those of a subcritical core because the neutron multiplication process becomes dominant.

(2) The accuracy both for the measured and calculated subcriticality has an essential importance for the design study on the ADSR. The requirement for the precision of neutronics calculation would become more severe than that for the conventional nuclear reactor, since the neutron multiplication does not depend on k_{eff} but approximately on $1/(1-k_{eff})$.

6 ACKNOWREDGEMENT

The KUCA experiments were performed as a joint study among Prof. Toshikazu Takeda's group of Osaka Univ., Prof. Yoshihiro Yamane's group of Nagoya Univ. and KURRI. The present study is partially supported by the Grant-in-Aid for Scientific Research (A) from the MEXT and the JAERI's Nuclear Research Promotion Program (JANP).

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