24P115-P

Performance of high temperature gas-cooled reactor as an outer tritium source for fusion reactors
核融合炉用外部トリチウム供給源としての高温ガス炉の特徴

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The performance of a gas turbine high-temperature reactor of 300 MWe nominal capacity (GTHTR300) as a tritium production device was examined by using $LiAlO_2$ compound. It was shown that if ^6Li was enriched between 7.5 wt% and 30 wt%, gas-cooled reactors with thermal output power of 3 GW in all can produce 2.5-7.5 kg of tritium in a year.

1. Introduction

To secure tritium supply to the first and subsequent fusion power-generation reactors at an early stage, it is important to prepare the plan to stably supply an adequate amount of tritium.[1] To solve this problem, we have proposed the use of a high-temperature gas-cooled reactor as a tritium producing device.[2] By assuming Li_2O, Li_2SiO_3, and Li_4TiO_4 compounds without ^6Li enrichment, the performance of the gas turbine high-temperature reactor of 300 MWe nominal capacity (GTHTR300)[3] was estimated.

To reduce the produced-tritium diffusive leakage from the device, $LiAlO_2$ is one of the most promising compounds.[4] Because this compound has Li density almost one-third by compared with Li_2O, however, enough amounts of Li cannot be loaded into the core region and the amount of tritium produced decreases regardless of remaining large excess reactivity.

In this study, we examine the performance of gas-cooled reactor as a tritium production device by using $LiAlO_2$ compound with ^6Li enrichment.

2. Analysis model

On the basis of the continuous-energy Monte Carlo transport code MVP-BURN[5], burn-up calculations for the entire-core region of GTHTR300 were carried out considering its unique double heterogeneity structure. Fig.1 presents the horizontal cross section of the GTHTR300 core and

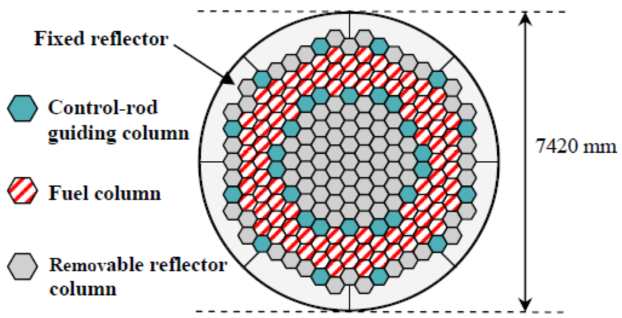

Fig.1 Horizontal cross section of GTHTR300 core

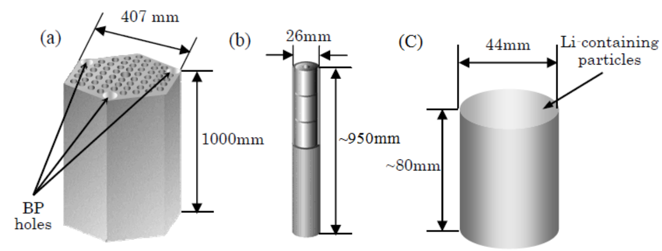

Fig.2 Schematic views of (a) fuel block (b) fuel rod and (c) Li compound pellet

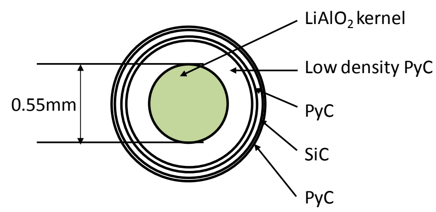

Fig.3 Schematic views of a ceramic-coated $LiAlO_2$ particle. 4 types of ^6Li enrichment is assumed for Li compounds in the calculations.

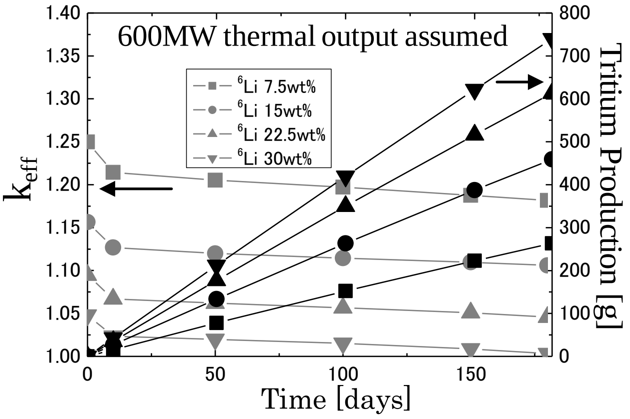

Fig.4 Time evolutions of the effective multiplication factor and the time-integrated weight of the tritium produced in the gas-cooled reactor for several ^{6}Li enrichments of $LiAlO_2$. Thermal output power is assumed to be 600 MW.

Fig.2 presents its schematic views of each fuel blocks. We can see that there is a large space near by the fuel regions and in fuel blocks. For example, removable reflector columns, control-rods and burnable poison (BP) holes are expected as a Li-compound loading space. In this paper, all BP compacts in the reactor are assumed to be replaced with Li-compound pellet which contains ceramic-coated $LiAlO_2$ particles (Fig.3). The operation parameters of the GTHTR300 assumed in this study are indicated in Table I.

Table I. Typical calculation parameters in the present system of gas-cooled reactor

Thermal Output power	600[MW]
^{235}U Enrichment	14[wt%]
Fuel Temperature	1360[K]
Moderator Temperature	1190[K]

3. Numerical result and conclusion remarks

We carried out the 180-day burn-up simulation of the gas-cooled reactor with 600 MW thermal output power by changing the ^{6}Li enrichment contained in Li compounds pellets.

The time evolutions of the effective multiplication factor and the time-integrated weight of the tritium produced in the gas-cooled reactor are shown in Fig.4 for several ^{6}Li enrichments. It was shown that the total amount of tritium produced in 180-day operation increases and excess reactivity decreases with increasing ^{6}Li enrichment. When 30 (7.5) wt% enrichment of ^{6}Li is assumed, the amount of tritium produced in 180-day operation is estimated as 750 (260) g. Although the loaded ^{6}Li weight increases almost 4 times, the amount of tritium produced in 180–day operation increases only 3 times. The reason can be seen in Fig.5. The normalized neutron flux averaged over the total volume of the $LiAlO_2$ particles and the ratio of ^{6}Li(n,t)^{4}He reaction rate R to the one when 7.5 wt% enrichment is assumed R_0 are shown in Fig.5 as a function of ^{6}Li enrichment. As ^{6}Li concentration in the particles increases, the neutron absorption at the outside layers in the Li-compound pellet increases. Because of the self-shielding effect, the neutron flux averaged over the volume of the $LiAlO_2$ particles decreases with increasing the enrichment.

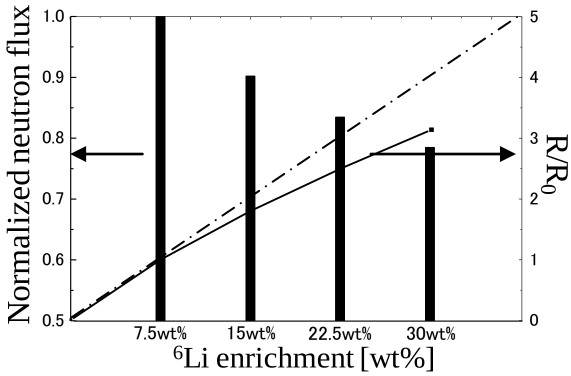

Fig.5 Normalized neutron flux averaged over the $LiAlO_2$ particles and relative ^{6}Li(n,T)^{4}He reaction rate R/R_0 for several ^{6}Li enrichments. Here R_0 is the reaction rate when 7.5 wt% ^{6}Li enrichment is assumed.

It is shown that when $LiAlO_2$ compound is used in the gas-cooled reactors with 3 GW thermal output power, 2.5-7.5 kg of tritium can be produced in a year. This study was performed under the condition not to change the original structural design of GTHTR300. In this study, we loaded Li compound in the original space prepared for BP insertion. At the presentation, the different Li loading patterns e.g., use of the control rod regions, will also be shown.

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