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Tritium production method for the demo fusion reactor by using the high-temperature gas-cooled reactor

高温ガス炉を用いた原型炉用初期装荷トリチウム調達法

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It is necessary to supply tritium for initial start-up of fusion reactor from an outside tritium source after ITER project, however, the method of tritium supply is not specifically decided. In this study, Li rod containing cylindrical Li compound in cladding tube is assumed to suppress tritium outflow and an amount of tritium production considering tritium outflow suppression is estimated. A possibility that tritium outflow can be suppressed while securing a sufficient amount of tritium production is shown.

1. Introduction

It is necessary to supply tritium for initial start-up of fusion reactor from an outside tritium source. We proposed the use of High Temperature Gas-cooled Reactor (HTGR) to produce tritium [1,2]. In our previous study, to show the efficacy of tritium production by HTGR, we estimated how much tritium can be produced in the case considering the securement of tritium production only. However, it is necessary to estimate tritium produced by using the loading method considering several factors when actually tritium production by HTGR is assumed. One of the factors is the suppression of tritium outflow from the region loading Li compound in the reactor core. It is desirable that most of produced tritium is contained in the region loading Li compound.

In this paper, we estimate an amount of tritium production by using the method of loading Li compound to prevent tritium outflow. We use Li rod containing cylindrical Li compound in cladding tube to suppress tritium outflow. An amount of tritium production considering outflow suppression with respect to the thickness of $LiAlO_2$ and cladding tube is estimated.

2. Analysis model

A Gas Turbine High Temperature gas-cooled Reactor of 300 MWe nominal capacity (GTHTR300) [3] with 600 MW thermal output is assumed as the calculation target. A fuel block of GTHTR300 has three BP insertion holes and Li rods are loaded in there. We assume that cylindrical $LiAlO_2$ is coated using Zr alloy and Al_2O_3 (Fig.1.a), and tritium flowing out from cladding tube is recovered by helium gas. It has been shown that Al_2O_3 has relatively small permeability of hydrogen isotope by Katayama et al [4].However, permeability of hydrogen isotope in Zr alloy is not examined enough. Therefore, cladding tube consisting of Al_2O_3 only (Fig.1.b) is assumed and tritium production is estimated in this paper. Using the continuous-energy Monte Carlo transport code MVP-BURN [5], burn-up simulations are carried out. An amount of tritium outflow is estimated from equilibrium solution for the tritium diffusion equation in the cladding tube.

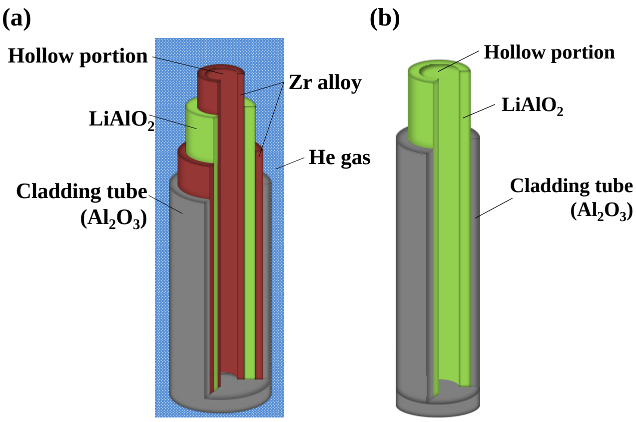

Fig.1. Schematic view of (a) Li rod to actually produce tritium and (b) Li rod to estimate tritium production in this paper

3. Calculation result

We estimate an amount of tritium production by fixing thickness of $LiAlO_2$ to 5 mm and changing cladding tube. Time evolutions of the cumulative weight of the produced tritium and the effective multiplication factor for fixed values of thickness of cladding tube are shown in Fig.2. Smaller thickness of cladding tube produced a more amount of tritium because thickness of $LiAlO_2$ is fixed and$LiAlO_2$ loading mass increases as thickness of cladding tube become smaller. To use GTHTR300 as tritium production device, the effective multiplication factor needs to keep over 1 during operation. The effective multiplication factor at the end of 180-day operation is far below 1 when the thickness of cladding tube is 8 mm. Maximum tritium production by using GTHTR300 with 600 MW thermal output power is 400 ~ 600 g depending on the thickness of cladding tube.

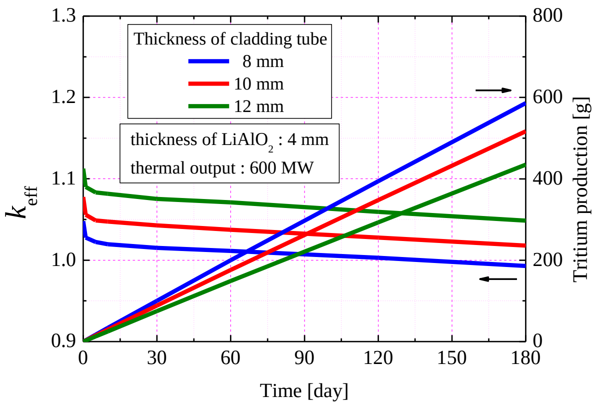

Fig.2. Time evolutions of the cumulative weight of the produced tritium and the effective multiplication factor

Next, we estimate how much tritium is flowed out into the reactor core in the case using this loading method. The relationship between tritium outflow rate and thickness of cladding tube, inner pressure of produced tritium in the cladding tube is shown Fig.3. Tritium outflow is inversely proportional to thickness of cladding tube and proportional to the square root of inner pressure of tritium. We assume that thickness of $LiAlO_2$ is fixed to 5 mm and cladding tube is a variable. Time evolutions of the cumulative weight of the tritium outflow and the inner pressure of produced tritium for fixed values of thickness of cladding tube are shown in Fig.4. When thickness is 10 mm, an amount of tritium outflow becomes smaller in comparison with the case being that of 7 mm. This reason is that thickness of cladding tube increases. On the other hand, when an amount of tritium outflow is compared between the thickness of 10 mm and 14 mm, that of 14 mm conversely increases tritium outflow from cladding tube in despite of larger thickness. This reason is that inner pressure of produced tritium increases due to the decrease of the diameter of hollow portion. Influence on tritium outflow by inner pressure of tritium becomes larger than that by thickness of cladding tube as inner pressure of tritium rises. It is necessary to optimize the thickness of $LiAlO_2$ and cladding tube.

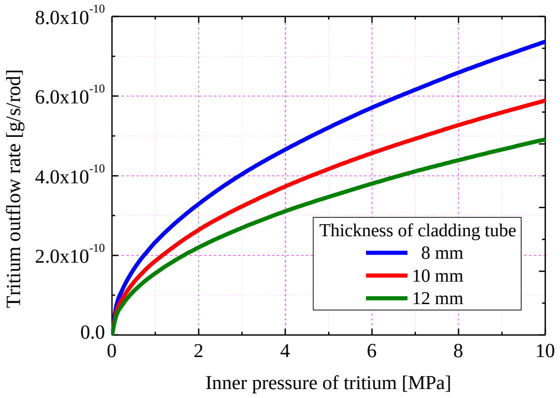

Fig.3. The relationship between tritium outflow rate and thickness of cladding tube, inner pressure of tritium in the cladding tube

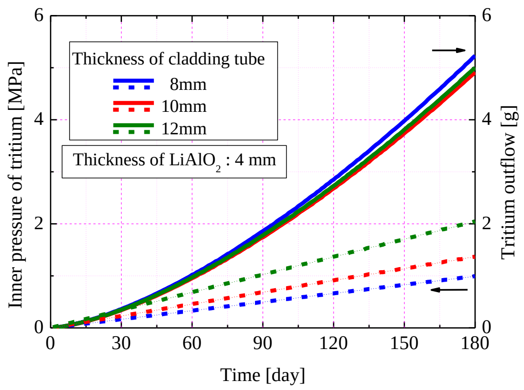

Fig.4. Time evolutions of the cumulative weight of the tritium outflow and inner pressure of produced tritium in cladding tube

4. Conclusion

We assumed the method of loading Li compound in consideration of tritium outflow prevention and estimated tritium production and outflow from the cladding tube into the reactor core. Tritium outflow is suppressed to several grams by the assumed method of loading Li compound. In the future, the thickness of cladding tube is optimized and tritium production considering outflow suppression is estimated. A possibility that tritium can be produced while suppressing a tritium outflow is shown.

References

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