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核融合・核分裂ハイブリット炉による Pu 燃焼の数値解析

Burn-up calculation of plutonium in fusion-fission hybrid reactor

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Introduction

Nuclear power plants (NPPs) are important as base load power source in the world even after Fukushima Daiichi nuclear disaster. However, NPPs have a problem in terms of nuclear proliferation because plutonium (Pu) is produced. Therefore, Pu should be burned up by some method.

This study focuses on a fusion-fission hybrid reactor to burn up Pu. A conceptual design of hybrid reactor has been carried out to put forward scenarios for Pu burn-up in terms of nuclear non-proliferation.

Research approach and Design requirements

Parameters of assumed hybrid reactor are shown in Table 1. They are based on ITER. In this study, the blanket of hybrid reactor consists of MOX fuel as neutron multiplier and heat source, Li_2TiO_3 as tritium breeder, water as coolant and F82H as structure material. This study uses simulation codes to obtain reactor performance. Neutron transport equation by Monte Carlo method and burn-up calculation are used for nuclear characteristic in hybrid reactors. Steady one-dimensional heat equation is used for heat characteristic in hybrid reactors.

There are five requirements to design feasible hybrid reactors for Pu burn-up, (1) the life-time of magnetic field coil is approximately over 40 years, (2) tritium breeding ratio (TBR) is over unity, and (3) the amount of burn-up Pu per year is over 7 t, (4) the temperature of each material is below its upper temperature limit, (5) hybrid reactors are self-sustained in electricity. The first target of this study is to find out parameters of hybrid reactor to meet the above five requirements.

Result and consideration

According to simulation results, the life-time of magnetic field coil is 50 years, TBR is 4.08. Figure 1 shows a reduction in the total amount of Pu. The initial loading plutonium is 22 t. After a year, it is reduced to 13 t, so that the amount of burn-up plutonium per year is 9 t. The highest temperature layer is MOX fuel in blanket. This layer temperature is 2000ºC. The upper temperature limit of MOX fuel is 2500ºC. Therefore this blanket is feasible thermally as well as other layers. This hybrid reactor is self-sustained in electricity and can supply annual average electric power of 1000 MW to grids. As a result, this hybrid reactor fulfills the five requirements. A next step is to make up operation scenarios of this hybrid reactor. In detail, it will assume Pu burn-up and T production for fusion reactor. In fact, hybrid reactor takes a role of a bridge between fission reactors and fusion reactors.

Table 1 Parameters of assumed hybrid reactor

Fusion power [MW]	150
Major radius [m]	6.2
Miner radius [m]	4.7
First wall loading [MW/m^2]	0.15
Blanket thickness [m]	1
Availability [%]	75
Magnetic field [T]	5.3
Current [MA]	15
Maximum heating power [MW]	73
Coolant flow velocity [m^3/s]	5.58
Coolant tube external diameter [cm]	1

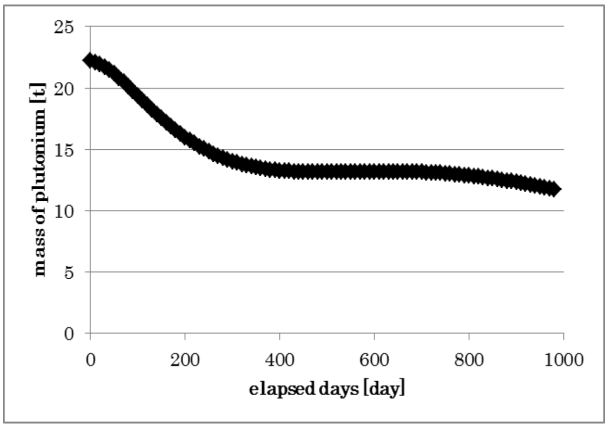

Figure 1 Time evolution of total Pu amount