Burn-up Calculation of Fusion-Fission Hybrid Reactor Using Thorium Cycle

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A fusion-fission hybrid system consists of fusion reactor with blanket containing nuclear fuel. Even for a relatively lower plasma condition, neutrons can be well multiplied by fission in the nuclear fuel and tritium is thus bread so as to attain its self-sufficiency. Enough energy multiplication is then expected and moreover nuclear waste incineration is possible.

In the present study, a burn-up calculation system has been developed to estimate performance of a fusion blanket under subcritical condition. In this system, track length data of neutron for each cell are stored in the MCNP-4B calculation. The data are fed directly to a routine for evaluation of one group cross-sections for burn-up calculation. The one group cross-section is made by the product of the track length data and the pointwise cross-section. With the cross-sections, burn-up calculation was performed by ORIGEN2. Burn-up cycle was repeated for necessary times.

A 3-dimensional ITER model was used as a base fusion reactor. The nuclear fuel (reprocessed plutonium as the fissile materials mixed with thorium as the fertile materials), transmutation materials (minor actinides and long-lived fission products) and tritium breeder were loaded into the blanket. The blanket consists of three layers, i.e., 1st one is on the plasma side, 2nd one is in the middle and 3rd one is the outer layer.

For an example of calculation results, the nuclear performance and transmutation efficiency are shown in Table 1. In this case, a plasma condition shown in Table 2 was employed. In the blanket, 8% reprocessed plutonium was loaded in the 2nd layer and 24% of the blanket was used for transmutation.

Table 1 Calculation Result

year	Power MW	TBR	Keff
0	6901	1.2478	0.7061
1	6466	1.2082	0.6946
2	6312	1.1731	0.6916
3	6042	1.1599	0.6791
4	5779	1.1415	0.6762
5	5746	1.1251	0.6651

Table 2 Plasma Parameter

Major radius (m)	6.2
Minor radius (m)	2.1
Plasma volume (m^3)	884
Plasma temperature (KeV)	19
Confinement time (s)	1.1
Electron density ($/m^3$)	4.80E+19
Fusion power (MW)	646
Neutron yeild (n/s)	2.20E+20
Neutron wall load (MW/m^2)	0.4
Plasma factor	0.7