Study on Optimal Configuration of a Tokamak Fusion System with Coupled Analysis of Tokamak Plasma and a Radiation Transport

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New simulation method which couples a conventional tokamak plasma analysis and a radiation transport analysis is developed. This simulation can incorporate both plasma physics and engineering constraints on a tokamak fusion system self-consistently. Using this simulation, we found not only plasma performance and system parameters, but also the optimal radial build of the tokamak fusion system with the plasma physics and engineering constraints moderately extrapolated from the constraints adopted in the design of International Thermonuclear Experimental Reactor (ITER). In a low-aspect-ratio configuration, the minimum major radius to produce a given fusion power was determined by the shielding requirements and the magnetic field at the toroidal field (TF) coil. With a confinement enhancement factor H = 1.3, $Q > 10$ was possible for fusion power greater than 1,000 MW with an aspect ratio of $A = 1.5$; however, $Q > 10$ was possible for fusion power greater than 2,000 MW with an aspect ratio of $A = 2.0$. In a normal aspect ratio configuration, configuration with only an outboard breeding blanket does not satisfy requirement on tritium self-sufficiency. The optimum system size to produce a given fusion power is determined by the requirements on the shielding, tritium breeding and the magnetic field at the toroidal field (TF) coil. With a confinement enhancement factor H = 1.3, Q > 30 was possible for fusion power greater than 2,000 MW with an aspect ratio of A = 3.0; however, Q > 30 was impossible with an aspect ratio of A = 4.0. The tritium breeding capability of a low-aspect-ratio tokamak exhibited better performance since the number of fusion neutrons that contributed to tritium breeding were larger than the case with a larger aspect ratio tokamak.