Self-consistent Analysis of a Blanket and Shielding of a Fusion Reactor Concept

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1. Introduction

To develop the concept of a DEMO reactor, a tokamak reactor system analysis code has been developed at KAERI (Korea Atomic Energy Research Institute) [1]. The system analysis code incorporates prospects of the development of plasma physics and the technologies in a simple mathematical model and it helps to develop the concept of a fusion reactor and to identify the necessary R&D areas for a realization of the concept. In the system code, a plant power balance equation and a plasma power balance equation are solved to find plant parameters which satisfy the plasma physics and technology constraints, simultaneously. The outcome of the system analysis is to identify which areas of plasma physics and technologies and to what extent they should be developed for a realization of given fusion reactor concepts.

2. Methods and Results

2.1 System Analysis Code

The design of a blanket and shielding play a key role in determining a size of a reactor since they are constraints for various reactor components. In this paper, we coupled a system analysis with a one-dimensional neutronic calculation to determine a reactor parameter in a self-consistent manner. Neutronic optimization is performed from the aspects of a tritium breeding ratio (TBR), nuclear heating, radiation damage to a toroidal field, etc. With a coupled system analysis and one-dimensional neutronic calculation, we assess various types of DEMO blanket concepts.

In a system analysis code, the mathematical models to capture the physics and technologies are an overall plant power balance equation and a plasma power balance equation. The first equation is the plasma power balance equation, which is represented as

$$P_{con} + P_{rad} = P_{OH} + P_{\alpha} + P_{CD}$$

where, the conduction (P_{con}) and radiation losses (P_{rad}) are balanced by a α particles heating (P_{α}), auxiliary heating (P_{CD}) and an ohmic heating (P_{OH}). These terms have a complex dependency on the plasma parameters.

The second is a plant power balance equation, which accounts for an energy multiplication, efficiency of an electricity generation and a power consumption in a current drive, cryogenics and other systems. The overall plant power balance includes complex dependencies on plant parameters. The plasma physics properties are expressed in a zero-dimensional model in the system analysis code. The basis of the physics models used in the system analysis code is the same as those used for the design of ITER [2,3]. The zero-dimensional model provides satisfactory results to select a reactor concept although it does not consider the profile effects precisely such as the heating and current drive profiles, the bootstrap current fraction, and an advanced tokamak operation with a negative shear, etc.

2.2 Engineering Constraints

There are various technology constraints such as a radial and vertical build, ripple condition, critical current density in a superconducting coil, startup and burn volt-sec capability, stress limit, divertor heat load limit, shield requirements, maximum TF field, etc. These constraints incorporate the prospects for the development of the relevant technology in the future. Amongst the various engineering constraints, the blanket and shielding are constraints for various reactor components. One-dimensional neutronic calculation is coupled with the system analysis code for a self-consistent determination of the dimensions of reactor components.

2.3 Algorithm for System Code

In the system analysis code, physics and engineering constraints are modeled into the plant power balance equation. The system code finds the design parameters under the plasma physics and engineering constraints or optimizes the design depending on the given figure of merits. We coupled the system analysis with one-dimensional neutronic calculation to determine the reactor parameter in self-consistent manner. Neutronic optimization is performed in the aspects of tritium breeding ratio (TBR), nuclear heating, radiation damage to toroidal field, etc. Fig. 1 shows the flow chart of the system analysis code.

3. Conclusions

We have developed a tokamak system analysis code which provides the design parameters of a fusion reactor concept in a self-consistent manner by coupling it to a one-dimensional neutronic calculation. Assessment of various blanket concepts will be possible by using the developed system analysis code.

REFERENCES

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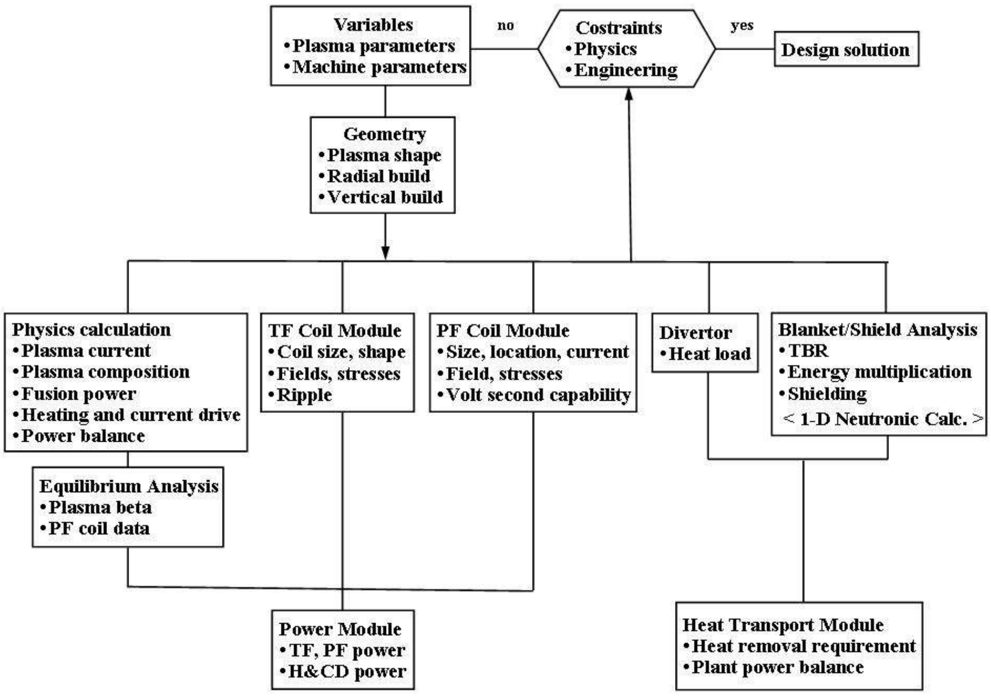

Fig. 1. The flow chart of the system analysis code.