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Study of DEMO Using the Structural Design of ITER
ITERの構造設計を用いた原型炉の検討

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Considering a breeding blanket installed in the ITER size TF coils to demonstrate the electric generation, the electric power for DEMO using the structural design of ITER is investigated. Assuming that the breeding blanket thickness is 1.2m, and so the minor radius is 1.4m. We have investigated self-consistent parameters for ITER size DEMO using a conceptual design code. It is shown that our designed reactor can operate P_{el}(Generator output) =135~180MW and Q=3.2~4.2, where β_N=3.0~3.5, $H_{H98(y,2)}$=1.1~1.2, and n_e/n_{GW}=0.45~0.50.This result suggests that DEMO using of the structural design of ITER can generate several hundred MW of P_{el} while the net output is small or in some cases, negative.

1. Introduction

ITER was designed under the international cooperation [1] and is currently under construction. The next step of ITER is considered a demonstration plant (DEMO) that can supply electric power actually. A DEMO conceptual design has been done by several groups so far [2]. Many of DEMO designs are larger size than ITER and have technical or engineering challenge. In order to construct DEMO, many expenses and periods are expected. Therefore, the design of low-cost DEMO that can be constructed immediately after experiments of ITER is important.

In this paper, we have investigated DEMO using structural design of ITER. By using the TF coils same as those of ITER, DEMO can be expected to construct early at lower cost. Assuming a breeding blanket, which must be thicker than the ITER shield blanket, the net and generator outputs have been estimated by using the design code.

2. Conceptual design code

Major Physics constraints concerned with reactor designs are shown as follows:

1. Plasma pressure limit (β_N)
2. Density limit n_{GW} (Greenwald density limit)
3. Safety factor q
4. Energy confinement performance

In our design code, based on the above constraints, we have investigated design parameters that satisfy the following conditions:

1. Driven current profile by external input, and the NBCD efficiency to achieve it by the neo-classical model [3]. The beam pressure is also estimated.
2. The amount of bootstrap current and profile
3. Fusion output and α-particle pressure by fusion reaction
4. Power balance in the plasma

These conditions have a nature that if any one changes, change the whole, so iterative calculation is required. A diagram of our conceptual design code is shown in Fig.1. By the design code it is possible to obtain self-consistent parameters in terms of plasma physics [4].

This paper discusses the electric power of fusion reactor by the above design code. TF Coils with the same size as ITER and tritium breeding blankets for electric generation are assumed. Assuming that the breeding blanket thickness is 1.2m, which is thicker than ITER shield blankets+VV (0.6m), so the minor

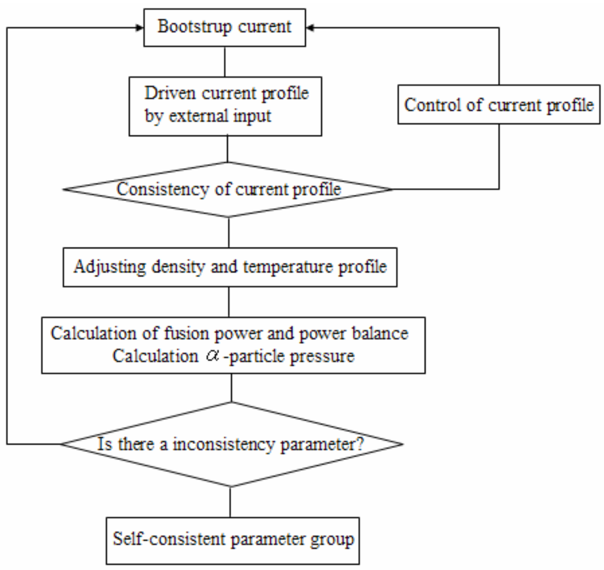

Fig.1. Design code diagram [4]

Table I. Design parameters

Parameter	
R/a (m)	6.2/1.4
A	4.43
κ_{95}/δ_{95}	1.9/0.45
I_p (MA)	8.4
q_{95}/q_0	3.13/1.45
B_T (T)	5.3
NBI energy (MeV)	1
Z_{eff}	2.07
f_m	1.4
η_{TD} (%)	30
η_{CD} (%)	60

radius a is reduced to a=1.4m from the design value of ITER (a=2.0m). The design parameters from these assumptions are shown in Table I.

In order to keep q_{95} larger than 3, I_p=8.4MA with κ_{95}=1.9 and δ_{95}=0.45 is required. The higher aspect ratio A or elongation κ, however, results in the vertical stability more unstable. Since the instability is critical at A=4.43 and κ_{95}=1.9, stabilization coils must be installed inside of the TF coils [2]. This is an engineering constraint of the present design.

By use of the fusion power P_{fus} and the external current drive power P_{CD} as calculated by the design code the thermal power P_{th} is written as $P_{th}=(0.8f_m+0.2)P_{fus}+P_{CD}$, where the factor f_m is the additional energy generated by nuclear reactions in the blanket, and was assumed that f_m=1.4 [2]. The generator output P_{el} is defined as $P_{el}=\eta_{TD}P_{th}$, where η_{TD} is the thermodynamic efficiency.

The auxiliary power needed in the whole plant is given by the re-circulation power for H & CD (P_{rec}) and the power used for the plant operation P_{OS}. P_{rec} is written as $P_{rec}=P_{CD}/\eta_{CD}$, where η_{CD} is the electrical efficiency of the CD system. The value of P_{OS} is estimated by the scaling law of the Generomak Model [5]. The net electric output $P_{el,net}$ is defined as $P_{el,net}=P_{el}-P_{rec}-P_{OS}$.

3. Result

The result obtained by the design code is shown Fig.2, where parameters of Table I are used. It is estimated that our designed reactor can generate several hundred generator output at n_e/n_{GW}=0.3~1.0. The high n_e/n_{GW}, however, reduces $P_{el,net}$ rapidly, because the higher H & CD power is required. Therefore, increasing n_e/n_{GW} increases P_{el}, but is unfavorable from the viewpoint of obtaining $P_{el,net}$. Our designed reactor can operate P_{el} =135~180MW and Q=3.2~4.2, at β_N=3.0~3.5, $H_{H98(y,2)}$=1.1~1.2 and n_e/n_{GW}=0.45~0.50, but $P_{el,net}$ is close to zero. To obtain the high $P_{el,net}$ with the positive P_{el}, therefore,

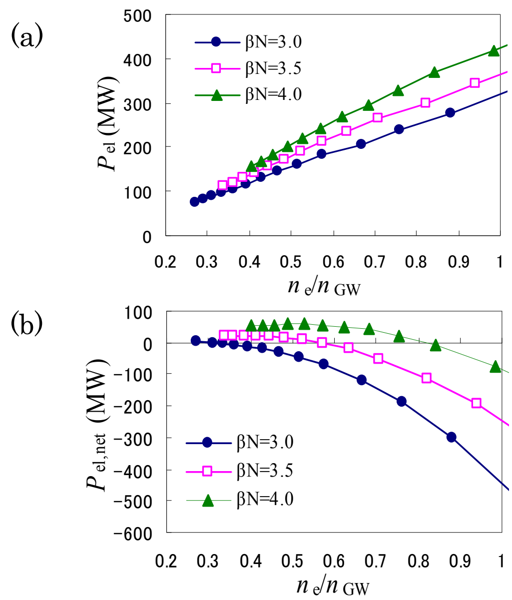

Fig.2. Variation of electric power versus n_e/n_{GW} in Table.I parameter when β_N varies between 3.0 to 4.0. (a) The generator output P_{el} is shown. (b) The net electric output $P_{el,net}$ is shown.

achievement of the high β_N which is larger than 4.0 is required. For example, $P_{el,net}$=56MW can be obtained at β_N=4.0, $H_{H98(y,2)}$=1.25 and n_e/n_{GW}=0.57.

4. Conclusion

Considering a breeding blanket installed in the ITER size TF coils to demonstrate the electric generation, the electric power for DEMO using structural design of ITER is investigated. Assuming that the breeding blanket thickness is 1.2m, and so the minor radius a is 1.4m. In order to design DEMO, we investigated self-consistent parameters using the conceptual design code. It has been shown that our designed reactor can operate P_{el} =135~180MW and Q=3.2~4.2, at β_N=3.0~3.5, $H_{H98(y,2)}$=1.1~1.2 and n_e/n_{GW}=0.45~0.50. Capable of operation in low n_e/n_{GW} is appeal of our design. And, it is revealed that slightly positive net output $P_{el,net}$ can be obtained in some cases, for example, 56MW with β_N=4.0, $H_{H98(y,2)}$=1.25 and n_e/n_{GW}=0.57.

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