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Improvement of Plasma Models in the System Code of Fusion Reactor PEC

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1. Introduction

In the previous study, the economy of tokamak fusion neutron source with normal conductive coil was determined by a system code PEC [1]. We studied plasma aspect ratio A dependence of the cost of the neutron source and found that the cost per neutron has its minimum around A ~ 2.2. In the previous study, the formulas given in [2] shown below are used for the bootstrap current faction f_{BS}, where β_{P}, κ, ρ, α_{T} and α_{n} are poloidal beta, plasma elongation, normalized minor radius, form factor parameters of temperature and density, respectively. We have assumed, $\alpha_{\mathrm{T}} = 1.0$, $\alpha_{\mathrm{n}} = 0.25$.

$$f_{\mathrm{BS}} = C_{\mathrm{BS}} f_{\mathrm{peak}}^{0.25} \beta_{\mathrm{P}} / \sqrt{A}$$

$$C_{\mathrm{BS}} = 0.773 + 0.019\kappa$$

$$f_{\mathrm{peak}} = \left(\int_0^1 (1-\rho^2)^{\alpha_{\mathrm{T}}} (1-\rho^2)^{\alpha_{\mathrm{n}}} \mathrm{d}\rho \right)^{-1}$$

Though f_{BS} depends on the safety factor q profile, it is not considered in PEC.

So, in this study, we evaluated the validity of bootstrap current faction model used in the system code analysis [1], comparing the results of the ACCOME code [3].

2. Models and conditions

The input parameters are shown in Table 1. These conditions come from the economic optimal design value of the previous study [1].

Table 1. Input parameters

Parameter	Value
Plasma major radius [m]	2.44
Plasma minor radius [m]	1.08
Elongation	2.30
Triangularity	0.50
Toroidal field [T]	3.10
Plasma current [MA]	9.40

The density n and temperature T profiles are represented by follows [1]. The n and T profiles were fixed since the particle and heat transport was not solved.

$$n(\rho) = 1.80 \times 10^{20} [\mathrm{m}^{-3}] (1-\rho^2)^{\alpha_{\mathrm{n}}}$$

$$T(\rho) = 15.0 [\mathrm{keV}] (1-\rho^2)^{\alpha_{\mathrm{T}}}$$

We assumed two co-tangential horizontal deuterium neutral beams (NBs) with its beam radius of 0.25 m and its beam energy of 800 keV. One is injected near the magnetic axis. The other is injected outside the magnetic axis on the equator plane. These powers are regulated for full non-inductive current drive. Then we added quasi-perpendicular deuterium NB with beam energy of 200 keV for heating. The total NB power is adjusted to 166 MW, the value used in the previous study [1].

3. Results

The profiles of total current density, beam driven current density, bootstrap current density, diamagnetic current density, and the safety factor are shown in Fig. 1. The safety factor has the value of 1.40, 3.98, 5.55 at the plasma center, $\rho = 0.95$, and the plasma surface, respectively.

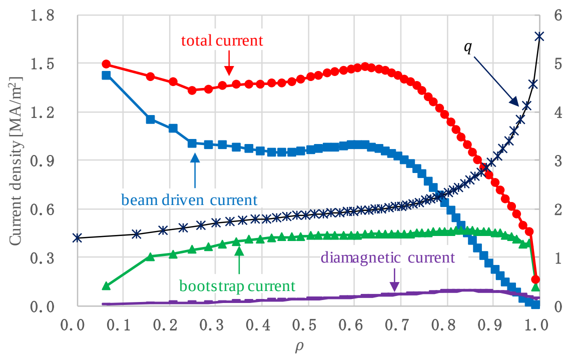

Figure 1. Current density and safety factor profile

The comparison of NB power P_{NB}, f_{BS}, beam-thermal fusion power $P_{\mathrm{f}}^{\mathrm{b-th}}$, thermal-thermal fusion power $P_{\mathrm{f}}^{\mathrm{th-th}}$, and the total fusion power $P_{\mathrm{f}}^{\mathrm{total}}$ are shown in Table 2. The value of f_{BS} of ACCOME analysis includes the diamagnetic current. The f_{BS} obtained by the ACCOME analysis was lower than the value obtained by the formula used in PEC. This results in higher tangential NB power and lower perpendicular NB power in the ACCOME analysis, which then results in lower $P_{\mathrm{f}}^{\mathrm{b-th}}$ and lower $P_{\mathrm{f}}^{\mathrm{total}}$. The analyze is in progress for other conditions of [1] aiming at improvement of formula for f_{BS} of a system code PEC.

Table 2. Comparison of P_{NB}, f_{BS}, $P_{\mathrm{f}}^{\mathrm{b-th}}$, $P_{\mathrm{f}}^{\mathrm{th-th}}$, and ,$P_{\mathrm{f}}^{\mathrm{total}}$

		P_{NB} [MW]	f_{BS}	$P_{\mathrm{f}}^{\mathrm{b-th}}$ [MW]	$P_{\mathrm{f}}^{\mathrm{th-th}}$ [MW]	$P_{\mathrm{f}}^{\mathrm{total}}$ [MW]
Pres.	tan	123.3	0.42	31.2	116.5	169
	perp	42.7		21.7		
Prev.	tan	62	0.62	15.5	112.4	180
	perp	104		52.0		

References

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