29E43P

安全性に着目したD-^{3}Heトカマク型核融合炉の概念設計
Conceptual Design of D-^{3}He Tokamak Fusion Reactor Focusing on Safety

細川康二，小川雄一，岡野邦彦
HOSOKAWA Koji, OGAWA Yuichi, OKANO Kunihiko

東大新領域
Graduate School of Frontier Sciences, the University of Tokyo

1. Introduction

The D-^{3}He fusion reactor has many advantages such as lower neutron productions and tritium inventory compared with D-T and D-D reactors from the safety point of view. Therefore, the D-^{3}He reactor is expected to be used as fusion energy source in the future.

In this study, we have investigated plasma physics and engineering condition on the D-^{3}He tokamak reactor. In addition, considering with secondary D-D reaction and tertiary D-T reaction, we estimate the neutron production, wall loading and the tritium fuel cycle in the reactor for the evaluation of safety.

2. Reactor design model and design constraints

The D-^{3}He reactor design has been analyzed with the conceptual design code (DRIVER) [1] which was modified to calculate the D-^{3}He reaction. Input parameters are listed in Table 1. In this study, we choose 5 MeV NBI because of high current drive efficiency at 50 keV plasma. The overall efficiency for current-drive system is assumed to be 80% assuming that the RFQ and the laser photo detachment neutralizer are used [2]. The parameters such as n_e/n_{GW}, β_N, H_{Hy2}, P_f are converged in self-consistent values. The value of q_{95} and q_0 are constrained to be more than 3.0, 1.0, respectively. $P_{e,net}$ and P_w are also restricted so that $P_{e,net} \geqq 1.0$ GW, $P_w \leqq 1.0$ MW/m^2, respectively.

All the tritium particles generated by the D-D reaction are reused as fuel in this reactor to minimize stored tritium. In line with this principle, the density of T in the plasma must be controlled to keep equality between the rates of its consumption and production as follows;

$$\frac{1}{2} n_D{}^2 \langle \sigma v \rangle_{D-D(p,T)} = n_D n_T \langle \sigma v \rangle_{D-T}. \quad (1)$$

3. Results

Figures 1 and 2 show the dependence of β_N and n_e/n_{GW} on A for R from 6 to 12. In Fig. 1, we plot β_N limit value as a function of A and κ induced by Lin-Liu et al [3] and some reactor β_N values [2, 4, 5].

Table 2 is a list of the reference design parameters which are indicated as 'design point' in Fig. 1 and Fig. 2, respectively. By Eq. (1), the ratio of tritium to fuel n_T/n_f is determined 0.0033 in this point.

References

[1] K.Okano, Y.Ogawa and H.Naitou, Plasma Phys. Control Fusion **32**, 225 (1990).
[2] F.Najmabaji, R.W.Conn, et al., UCLA report UCLA-PPG-1384.
[3] Y.R.Lin-Liu, R.D.Stambaugh, Nucl. Fusion **44** (2004) 548
[4] K.Tobita, S.Nishio, M.Sato, et al., Nucl. Fusion **47** (2007) 892.
[5] H.Shimotohno, et al., Fusion Eng. Design **69** (2003) 675.

Table 1. Input parameters

Elongation κ_{95}/Triangularity δ_{95}	2.0/0.35
NBI energy E_b (MeV)	5
Effective charge Z_{eff}	1.76
Effective reflection coefficient of wall R_{syn}	0.95
Thermal conversion efficiency η_{TD} (%)	45
Current drive system efficiency η_{CD} (%)	80

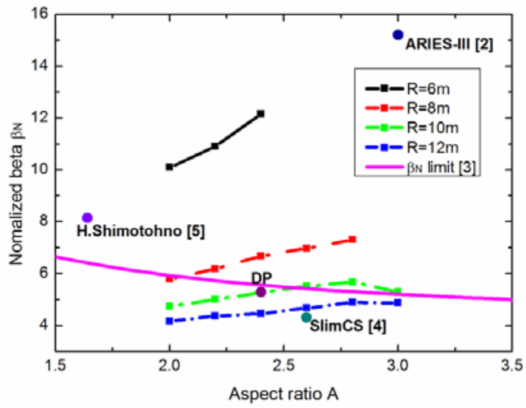

Fig.1. Variation of normalized beta versus aspect ratio for R from 6 to 12.

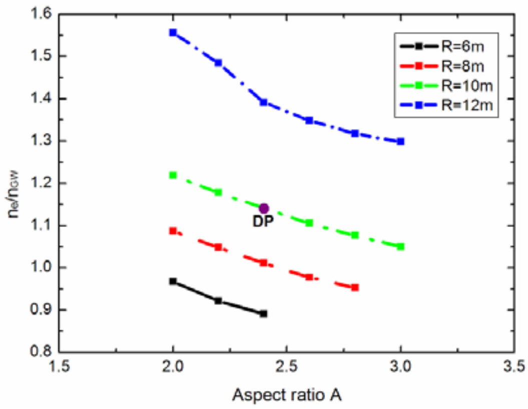

Fig.2. Variation of n_e/n_{GW} versus aspect ratio for R from 6 to 12.

Table 2. Reference design parameters

R/a (m)	10/4.17	I_p (MA)	60
A	2.4	f_{BS}	0.86
T_e/T_i (keV)	46/50	q_{95}/q_0	3.79/2.1
n_e/n_f (10^{20}m^{-3})	1.25/0.79	H_{Hy2}	1.88
n_{3He}/n_D	1	P_f/P_{con} (MW)	2900/778
n_T/n_f	0.0033	P_{br}/P_{syn} (MW)	942/1080
n_e/n_{GW}	1.14	$P_{e,net}$ (MW)	1150
B_T (T)	7.2	$P_{w,n}$ (MW/m^2)	0.082
β_N/β_t	5.28/0.11	$P_w/P_{w,div}$ (MW/m^2)	0.82/30.9