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Effect of aspect ratio on optimized profile and beta limit for tokamak DEMO reactor

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A tokamak DEMO reactor was proposed [1], where the aspect ratio A was 3.5. In this paper, we examine how much figures of merit such as beta limit or fusion power if A is changed. MHD stability is expected to be improved by larger magnetic well for smaller A, particularly at the edges compared to the core because of the geometrical effect. Note that, the aspect ratio was changed by changing the plasma minor radius under a fixed major radius in this study.

Plasma equilibria are obtained by using GOTRESS (EPED1)[2], ACCOME[3], and MEUDAS[4]. Then the ideal MHD linear stability was analized by using MARG2D[5][6] for toroidal number $n = 1, 2, 3, 4, 5, 10, 15, 20, 30, 50$. GOTRESS calculates steady-state profiles for given density and safety factor profiles by considering heat transport. In this study, only the EPED1 option was used for obtaining optimized profiles in the pedestal region. The ACCOME code and the MEUDAS code are used for solving the Grad-Shafranov equation. The ACCOME code calculates the equilibrium taking into account the bootstrap current density profile self-consistently determined from the density and temperature profiles. The density and temperature profiles in the core region are optimized to obtain a highest beta value against ideal MHD modes under the fixed pedestal profiles optimized by GOTRESS (EPED1) code. MARG2D code determines ideal MHD stability of tokamak equilibria by solving an eigenvalue problem associated with the Newcomb equation.

In this study, triangularity, ellipticity, major radius, safety factor at plasma edge q_{95} were kept almost unchanged, and the A was changed through plasma minor radius. The total plasma current was changed to keep q_{95} unchanged. The total current was composed by the self-consistent bootstrap current and an additional, externally-driven cuurent. The conducting wall was placed at 2.5 times the plasma minor radius, and thus the stabilizing effect of the conductive wall was not expected.

Figure 1 shows optimized pressure and safety factor profiles. Little change was observed in the pedestal region. The reason for this was that current-driven modes, not pressure-driven modes, were dominant in determining the pressure limit of the pedestal. Since the current-driven mode is not affected by the cross-sectional shape, the pressure limit of the pedestal was not improved by increasing the effect of the magnetic wells. The achieved normalized beta limits were $\beta_N = 3.41, 3.25$ and 3.20 for $A = 3.0, 3.3$ and 3.5, respectively. The beta limit increased mildly as the A was decreased. This comes from the difference of the q profiles in the core region. The kink-ballooning mode determined the beta limit in all cases. If the stabilizing effect of the conductive wall is not taken into account, a low n kink ballooning mode tends to destabilize first, not the high n ballooning mode. Table 1 summarizes the parameters of interest in this study. Although the increase of the beta limit is not big, the fusion power increased significantly as A is decreased from 3.5 to 3.0.

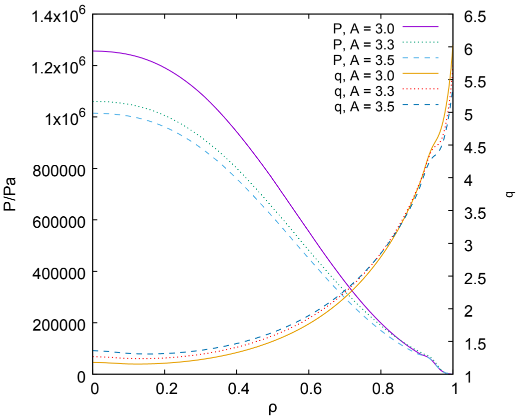

Figure 1: Optimized Pressure and safety factor profiles. Solid, dotted and dashed curves are for $A = 3.0, 3.3$ and 3.5, respectively.

Table 1: Characteristic parameters for three aspect ratios. R and a are in m, j_{BS} and j_{total} are in MA.

	$A = 2.99$ ($R = 8.480$, $a = 2.834$)	$A = 3.30$ ($R = 8.479$, $a = 2.571$)	$A = 3.50$ ($R = 8.469$, $a = 2.420$)
Ellipticity κ	1.744	1.760	1.756
Triangularity δ	0.369	0.363	0.359
Area [m^2]	40.6	33.7	30.5
Pfusion [GW]	2.10	1.51	1.26
Normalized beta β_N	3.411	3.245	3.197
Safety factor at plasma edge q_{95}	4.56	4.49	4.37
Bootstrap current ratio f_{BS}	48.2 % ($j_{BS} = 7.709$, $j_{total} = 16.0$)	50.8 % ($j_{BS} = 6.756$, $j_{total} = 13.3$)	52.8 % ($j_{BS} = 6.286$, $j_{total} = 11.9$)

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References

[1] Y. Sakamoto, K. Tobita *et al.*, 25th IAEA Fusion Energy Conference (St. Petersburg, Russia, 2014) FIP/3-4Rb.

[2] M. Honda, N. Aiba, H. Seto, E. Narita and N. Hayashi, Nucl. Fusion **61** (2021) 116029 (13pp).

[3] K. Tani, M. Azumi and R. S. Devoto, J. Comput. Phys. **98**, 332 (1992).

[4] M. Azumi, G. Kurita, T. Matsumura, T. Takeda, Y. Tanaka and T. Tsunematu, Proc. 4th lnt. Symp. on Comput. Methods Applied Sci. Engineering, Paris (North-Holland, Amsterdam, 1980), p. 335.

[5] Shinji Tokuda, Tomoko Watanabe, Phys. Plasmas **6**, 3012 (1999).

[6] Nobuyuki Aiba *et al.*, Comput. Phys. Commun. **175**, 269 (2006).