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原型炉概念構築に向けた物理設計の進捗
Progress of Physics Design for JA DEMO Concept development

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Introduction:

The Japan-wide pre-conceptual DEMO design activity is conducted by the Joint Special Design Team for fusion DEMO to establish the JA DEMO concept. In order to increase the feasibility of JA DEMO concept, the physics design focuses on (i) compatibility between core and divertor plasmas, (ii) assessment of the effect of conducting shell on vertical stability and high beta access, (iii) core transport modelling including pedestal and pellet, and so on.

Compatibility between core and divertor plasmas:

One of the major physics issues in a large-sized steady-state tokamak is the compatibility between core density and divertor detachment because of the low Greenwald density limit due to high q_{95} and large R_p. Requirements for divertor plasma design are (i) peak heat load on divertor target plate less than $10 MWm^{-2}$ for heat removal, (ii) T_e in attached area less than 20-30 eV for avoiding significant net erosion of W mono-block, and (iii) Ar impurity concentration in SOL less than 0.5-1.0%. In order to investigate lower boundary of core density to be compatible with above requirements, massive parameter scan has been performed by SONIC divertor plasma simulation for JA DEMO. The results indicate that the separatrix density of $n_e^{sep} > 2.1 x 10^{19}$ m^{-3} satisfies above requirements, which is roughly consistent with the pedestal density of $\sim 6.6 x 10^{19}$ m^{-3} in JA DEMO.

Assessment of the effect of conducting shell on vertical stability and high beta access:

The vertical stability is investigated by MHD equilibrium control simulator (MECS) including 3D eddy current effects. The ramp-up scenario is successfully developed by considering βp and li based on transport simulation, indicating that elongation of 1.75 is achievable in JA DEMO.

The MHD stability analysis for JA DEMO is performed by using MARG2D. The beta limit without conducting wall is $\beta_N \sim 2.6$, while $\beta_N \sim 3.5$ when the conducting wall is located at $r_W/a = 1.35$. Further improvements are observed with decreasing wall radius, for example $\beta_N \sim 3.9$ at $r_W/a = 1.30$.

Core transport modeling:

In order to establish the operation scenario, time dependent transport analysis is performed by using CDBM transport model. By optimizing the heating scenario, the steady-state operation condition is preliminary obtained for JA DEMO, indicating that ECCD has important roles for maintaining and controlling the internal transport barriers.

Based on the evaluation on the pedestal density, pedestal and ELM modelling are performed by EPED1 model and MARG2D stability code, suggesting that the pedestal temperature is ~3 keV and the equilibrium is near kink/peering stability boundary which can be regarded as the QH-mode regime. Furthermore, pellet ablation and drift simulation is performed by using HPI2 code based on the evaluation of pedestal density and temperature, indicating that the pellet with speed of 2 km/s and mass of $4x10^{21}$ atom/pel can deposit at $r/a \sim 0.85$ from the high field side top injection with poloidal angle of 120 degrees.