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核融合原型炉におけるプラズマ位置制御解析
Analysis of Plasma Position Control for DEMO Reactor

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Pre-conceptual designs of DEMO reactor have proceeded under collaboration Japan and Europe (Broader Approach activities (BA)). While the plasma elongation as high as possible is required for high plasma performance, the elongated tokamak plasma is unstable for the vertical motion in principle. Therefore, it is necessary for the tokamak devices to provide the position control system, which consists of passive conducting shells and active feedback control coils for positional stability. It is important for DEMO reactor to take into account the actual shape of vacuum vessel and in-vessel components since the design condition of DEMO reactor is different from current tokamak devices and ITER. There are several issues for the DEMO plasma position control as described below:

1) More clearance between plasma surface and passive conducting shells must be given to install the breeding blanket modules.
2) Magnetic detectors to estimate the plasma position are influenced by the noise generated from the eddy currents in the breeding blanket modules.
3) The conducting shell must be divided for the maintenance in the case of DEMO reactor.

In this study, we focus the influence on the plasma position control by the restriction as above.

The numerical model is assumed as follows: a) the plasma model is assumed as the rigid one which the plasma current density profile is taken into account, b) the in-vessel components and the vacuum vessel are approximated as 3-dimensional thin-layer structure, and c) the time evolution of eddy currents and coil currents is expressed as circuit equations.

The main parameters of plasma used for numerical simulation are the major radius R_p=8.2m, the minor radius a_p=2.57m, the plasma current I_p=14.6MA, the elongation κ_{95}=1.65, the triangularity δ_{95}=0.33, the safety factor q_{95}=4.2, the poloidal beta β_p=1.8, the plasma internal inductance l_i=0.9 and the decay-index n=-0.81. According to results by power balance analysis, the fusion power output is 1.5GW. The conducting shells in this study are separated into 48 parts (7.5 degree) in toroidal direction for feasibility of maintenance scheme.

Fig.1 shows the time evolution of the plasma position in vertical and radial directions. The solid and dotted lines represent plasma position and estimated value by detectors, respectively. The plasma position agrees very well with the estimated value although there is the noise from the blanket modules.

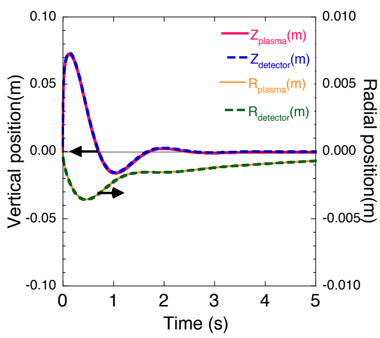

Fig.1 Comparison between plasma position and estimation by detectors (flux loop coils)

The numerical simulation was carried out to evaluate control coil power of DEMO reactor in the cases of κ_{95}=1.65 and β_p=1.8/0.1. The Vertical Displacement Events (VDE) and β_P drop are adopted as the main disturbance. Table 1 shows results of control coil power and the maximum displacement from initial plasma position using VDE.

Table 1. Simulation results by VDE

	Minimum control coil power (MW)	Maximum displacement (m)
β_P=1.8	6.1	0.061
β_P=0.1	9.9	0.081

The control coil power is less than 10MW in Table1, which is acceptable for DEMO reactor. The numerical results in the case of β_P drop are shown in Table 2.

Table 2. Simulation results by poloidal beta drop

	Minimum control coil power (MW)	Maximum displacement (m)
β_P=1.8 →1.7	32	0.034
β_P=1.8 →1.6	129	0.068

In the case of β_P=1.8→1.6, it seems to be difficult to supply the control coil power. Therefore, the large β_P drop needs some kind of countermeasure.