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# MHD平衡制御シミュレータを用いた高楕円度プラズマの垂直位置安定性の研究

# Study of vertical stability for high elongation plasma by using MHD equilibrium control simulator

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The extension of the plasma cross-section in a vertical direction is effective for improving the plasma performance, but this elongation plasma likely becomes unstable in the vertical direction due to the distortion of vertical magnetic fields produced by poloidal field (PF) coil currents. The vertical plasma position is controlled by combining the magnetic fields produced by active PF coil and the passive eddy currents flowing in the passive structures. The vertical displacement event (VDE) likely occurs if the vertical stability is reduced with increase in the elongation of plasma cross-section and plasma current profile parameter $l_\mathrm{i}$ and decrease in the plasma pressure parameter $\beta_\mathrm{P}$. The vertical stability is improved if the passive structures such as vacuum vessel (VV) and in-vessel components are close to the plasma or their resistances are small. It is expected that the vertical plasma position control becomes more sensitive in DEMO and future fusion reactors, which require the high elongation plasma and are difficult to put active coils and passive structures close to plasma in order to install a blanket module in the VV and ensure the maintainability of in-vessel components. For controlling the high elongation plasma in such situation safety and stably, it is essential to understand the impacts of the geometry of passive structures on vertical stability under the active and passive control.

An MHD equilibrium control simulator (MECS) has been developed in order to study the techniques of plasma equilibrium control for JT-60SA. The MECS consists of modules of plasma simulator, plasma shape reconstruction, plasma controller to simulate a real plasma equilibrium control. The plasma simulator predicts the self-consistent plasma equilibrium with eddy currents by solving Grad-Shafranov equation under the given PF coil currents and plasma internal parameters momentarily. The controller adopts the ISOFLUX control scheme for the control of plasma position and shape, and its controller modifies the PF coil currents to decrease the residuals between poloidal magnetic flux value at the plasma boundary and that at the control points which specify the plasma position and shape. By linking these modules, the feedback control of the plasma equilibrium can be simulated within the power supply capability.

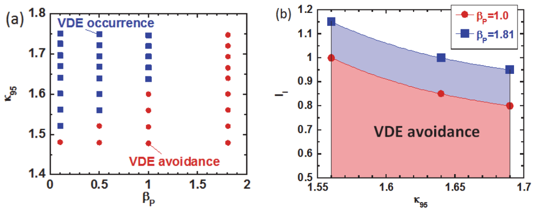

Figure: (a) Relationship between elongation of plasma cross-section $\kappa_{95}$ and $\beta_\mathrm{P}$ at $l_\mathrm{i}$ of 0.9 and (b) one between $\kappa_{95}$ and $l_\mathrm{i}$ at $\beta_\mathrm{P}$ of 1.0 and 1.81 with passive structure models.

In the MECS simulation, the vertical position of plasma diverges with time when the VDE occurs due to the reduction of vertical stability with increases in elongation of plasma cross-section and $l_\mathrm{i}$ and decrease in $\beta_\mathrm{P}$. Then, an operation region avoiding the VDE is assessed by exploring a proper relationship between elongation of plasma cross-section, $l_\mathrm{i}$ and $\beta_\mathrm{P}$, which the vertical position of plasma converges with time. The elongation of plasma cross-section can be increased with avoiding the VDE by changing the $\beta_\mathrm{P}$ and $l_\mathrm{i}$ based on the assessed operation region as shown in Fig. Also, the operation region is extended by improving a stabilizing effect of passive structures on VDE. The impacts of the geometry of passive structures on the operation region and plasma discharge scenarios avoiding the VDE will be investigated using MECS in a tokamak device which is difficult to put active coils and passive structures close to plasma like DEMO reactor.