Effect of toroidal and poloidal cut on eddy current in conducting liner for vertical position stabilization in QUEST

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Spherical tokamak has a natural elongation thanks to low aspect ratio. But QUEST has a divertor configuration of higher elongation κ with negative n-index. Therefore vertical position instability must be stabilized by conducting shell and feedback control.

As the conducting shell, we are going to set a liner of copper. We consider passive model of the liner for vertical stability analysis first. The liner is divided into segments, and each segment is approximated as toroidally symmetric passive poloidal coils. The plasma is considered in two ways based on rigid model and variant shape model. In case of the rigid model, linear growth rate of the vertical plasma position is calculated from eigenvalue analysis of equation of vertical motion of plasma center. Stabilizing effect of the liner to vertical position instability using rigid shape model is like figure "*S*" as a function of growth rate. Since frequency of the inverter for horizontal field coil is 3 kHz, vertical position instability may be controllable when the growth rate is smaller than 700 s^{-1}, and can be controllable when it is smaller than 200 s^{-1}. Standard divertor configuration of $\kappa \sim 1.6$ ($n > -0.1$) can be controllable even when thickness of the Cu liner is 0.1 mm. But we must test whether divertor configuration of high $\kappa \sim 2$ ($n \sim -0.28$) is controllable or not. Liner thickness dependence of growth rate of unstable mode ($n = -0.28$) is linear, since the growth rate is proportional to the resistance.

Growth rate based on variant shape model is about 2 times as large as the one from rigid model. Growth rate of $n \sim -0.1$ is about one tenth of $n \sim -0.28$, it becomes 200 s^{-1} for thickness 0.1 mm (copper) even in the variant shape model. The vertical position instability can be controllable for thickness 4 mm (Stainless Steel) at room temperature.

In real spherical tokamak, however, toroidal current happens to flow in the conducting liner, when center solenoid coil current is made fall down to induce plasma current. Therefore toroidal cut should be made in the liner though the stabilizing effect is decreased. As for the poloidal cut, no existence of the cut is venefitial from a viewpoint of the construction, but the stabilizing contribution of the vertical eddy current crossing equatorial plane is large.

When the conducting liner is cut in toroidal and poloidal direction, the liner is divided into triangle elements, and eddy current in each thin plate is represented by current potential at each nodes. The Lagrangian's equation concerning magnetic energy and Joule loss is analyzed by utilizing a program EDDYCAL (JAEA) and effect of the cut on the stabilization is studied: the number of the cuts, the separation width, etc. Using rigid model, linear growth rate of the vertical position is calculated from eigenvalue analysis similarly with the passive poloidal coil model mentioned above. The two toroidal cuts may increase the growth rate twice and the one poloidal cut together with the toroidal cuts may increase it twice further. The thickness and temperature dependences coincide with linear dependence of the growth rate on the resistance.