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Three dimensional effects of MHD control in JT-60SA
JT-60SA の MHD 制御における 3 次元効果

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RWM active control system for JT-60SA is being designed in order to achieve a steady-state high beta plasma and also to clarify the stabilization mechanism of RWM to be extrapolated toward ITER and DEMO. The assessment of 3D effects of RWM control on plasma are very important for JT-60SA, because the side-band magnetic field induced by RWMC is very large due to very small coverage area of plasma surface with coils. We performed some experiments on the RFX-mod device with a reduced sets of coils to simulate the JT-60SA RWM control. RWM can be controlled with very small number of RFX coils however sideband effects emerged and decreased the plasma performance.

To achieve a steady-state high beta plasma, suppression of resistive wall mode (RWM) is necessary because the no-wall beta limit of a steady state plasma with a large bootstrap current fraction is relatively low. Therefore, an RWM active control system for JT-60SA is being designed [1], in order to clarify the stabilization mechanism of RWM to be extrapolated toward ITER and DEMO.

Figure 1 shows in-vessel coils of JT-60SA with the half of stabilizing plate (SP) and a part of the vacuum vessel (VV). RWMCs are mounted on the SP beside the plasma. There are six sectors of RWMCs, each consisting of upper, equatorial, and lower rectangular “picture frame” coils, amounting to a total of 18 coils that are individually fed by 18 power supplies.

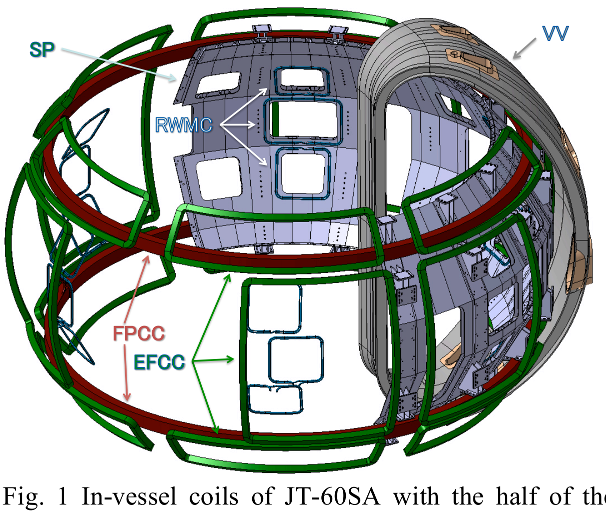

Fig. 1 In-vessel coils of JT-60SA with the half of the stabilizing plate (SP) and a part of the vacuum vessel (VV).

The problem of 3D effects of RWM control on plasma is very important for JT-60SA, because the coverage area of plasma surface with coils is very small as shown in Fig. 1. Therefore, we performed some experiments on the RFX-mod device [2] implementing with a reduced sets of coils only on selected modes [3,4] in order to investigate the RWM controllability and plasma deformation caused by sideband magnetic field induced by RWMC. The RFX-mod is fully covered by the active control coils, which consist of

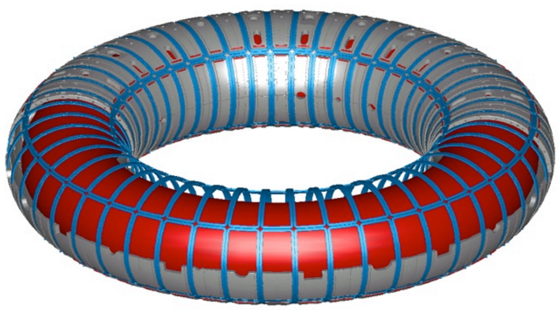

Fig. 2 Active control coils of RFX-mod

4 coils in the poloidal direction (top, bottom, inside and outside) and 48 in the toroildal direction, total 192 coils, as shown in Fig. 2. Each coil has an independent amplifier and successfully controls RWMs and tearing modes.

We have tried to suppress the m=2,n=1 RWM of RFX-mod tokamak discharges with reduced sets of control coils. Figure 3 (a) shows the temporal evolution of plasma current (I_p) and safety factor at plasma edge (q_{edge}) of the typical tokamak discharge for this experimental campaign with tooloidal magnetic field of 0.5T, constant I_p=170kA and q_{edge}~1.8. It is very useful for RWM physics study that the growth rate of RWM in RFX tokamak discharge is constant because the RWM can be destabilized at constant certain safety factor at plasma edge (q_{edge}), whereas RWM in almost other tokamak can be destabilize during only q_{edge} is decreasing. The numbers of coils for RWM control are decreased from 192 to 48, 24, 12, and 6 mounted on the low field side of the plasma as with those of JT-60SA. Figure 3 (b) shows the m=2,n=1 RWM amplitude controlled with only 6 coils. RWM can be stabilized with sufficient gain (Kp=12000) and the growth rate is almost same without FB at from 500 ms to 530 ms and after 800 ms.

RWM can be controlled with coils covering very small fraction of plasma surface as described above, however, degradation of plasma performance by sideband effects were observed in RFX-mod RFP discharges. RFX-mod can perform a certain RWM stabilization with or without sideband stabilization with full coils. Figure 4 shows the effect of sideband mode. RWMs are stabilized with only eight coils without stabilization of some sideband modes as shown in Fig 4 (b). For instance, if we use the eight coils in the toroidal direction for stabilize m=1, n=-6 mode, the coils induce m=1, |n|=2, 10, 14, 18, 22 sideband modes as shown in Fig. 5. In the shot of 28311,

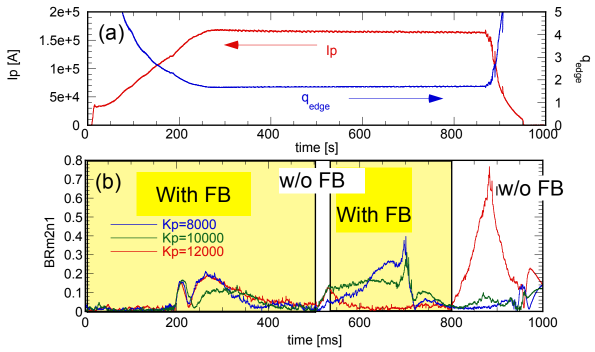

Fig. 3 Temporal evolution of plasma current (I_p) and safety factor at plasma edge (q_{edge}) of RFX-mod tokamak discharges (a) and m=3,n=1 RWM mode amplitude with different gains (b). RWM control was stopped between t=500-530s and after t=600s.

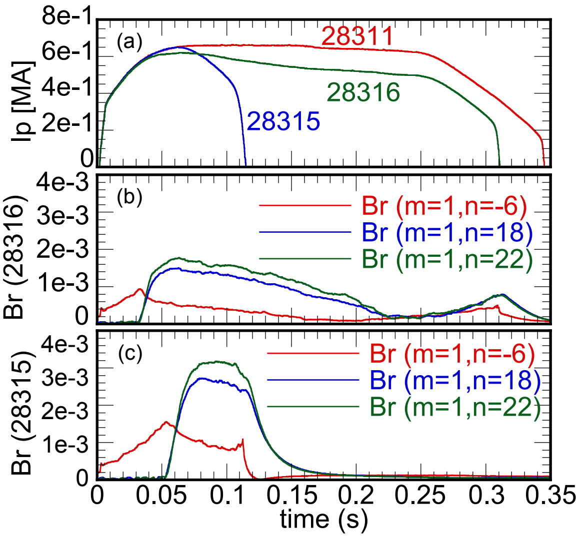

Fig. 4 Temporal evolution of plasma current (a), stabilized m=1,n=-6 RWM amplitude and m=1,n=18, 22 sideband amplitude of 28316 (b) and 28315 (c)

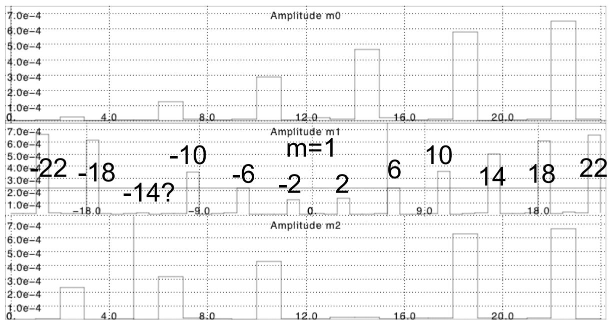

Fig. 5 Fourier components of magnetic field induced by 1x8 RFX-mod coil configuration optimized to control the m=1,n=-6 RWM. Side band amplitude of m=1,n=18, 22 are much larger than the main component.

m=1,n=-6 mode and sideband mode are stabilized from the beginning of discharge. In the shots of 28315 and 28316, m=1,n=-6 mode are stabilized from 0.03s and 0.05s, respectively, without sideband stabilization. Larger m=1,n=18, 22 modes appear due to larger coil current and after that plasma current decrease. Finally, plasma was terminated due to large sideband mode on 28315. We will investigate the deformation of plasma surface due to sideband effects of JT-60SA RWMC by using the 3D MHD equilibrium codes.

References

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