27th EPS Conference on Contr. Fusion and Plasma Phys. Budapest, 12-16 June 2000 ECA Vol. **24B** (2000) 332 -335

Magnetics Control of Korea Superconducting Tokamak Advanced Research (KSTAR) Plasmas

Hogun Jhang[a], Jin-Yong Kim[a], S. H. Ku[b], K.-I. You[a] , and D. K. Lee[a]

[a] Korea Basic Science Institute, Taejeon, Korea
[b] Korea Advanced Institute of Science and Technology, Taejeon, Korea

The magnetics control requires the static and dynamic controls of plasma equilibrium parameters by magnetic means. In KSTAR[1], this is realized by controlling the currents in poloidal field (PF) coils, inner control (IC) coils, and Field Error Correction/Resistive Wall Mode (FEC/RWM) coils. Figure 1 shows the locations of PF coils and IC coils, and Fig. 2 represents a schematic diagram of FEC/RWM coils. In the present paper, we report the progress in the study of magnetics control in KSTAR. The topics covered in this paper comprises (1) plasma equilibria, (2) fast position control, (3) plasma current and shape control, (4) non-axisymmetric error field compensation, and (5) control of resistive wall mode.

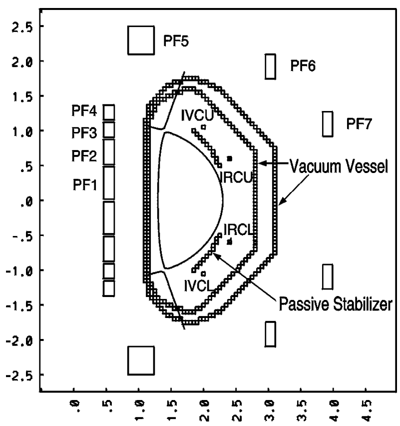

Fig. 1.Axisymmetric model of KSTAR

Fig.2. Schematic diagram of FEC/RWM coils in KSTAR

Figure 3 shows the steady-state operating space, which KSTAR experiments are expected to explore. A plasma equilibrium corresponding to a point in the $l_i(3)-\beta_N$ space can be calculated by solving a free-boundary equilibrium problem. The equilibrium solver calculates the PF coil currents, which satisfy shape constraints and flux linkage through a reference position. Since the PF coils are made of superconductors, there is a limitation of allowable current for each PF coil. An ohmic operation window for each equilibrium can be identified by calculating superconducting allowables of PF coils. Figure 3 (b) represents the operation window for 7 equilibria, corresponding to corners of $l_i(3)-\beta_N$ space. The PF coils of KSTAR is sized to be capable of exploring full $l_i(3)$-β_N space for realistic flux states ranging from 2 Wb to 8 Wb.

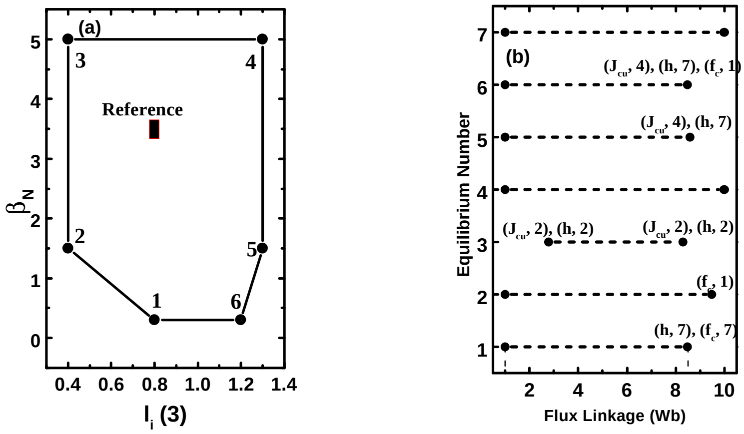

Fig 3. (a) Steady-state operating space for full-current (2 MA) KSTAR plasmas. (b) Ohmic operation window for seven equilibria.

The fast time-scale plasma position control is realized by using two pairs of inner control coils inside the vacuum vessel (Fig. 1). The Inner Vertical Coil (IVC) is used for the control of unstable vertical movements, while Inner Radial Coil (IRC) is used for the control of rapid radial motion. The maximum feedback current (voltage) for IVC has been founded to be 42 kA-turns (123 V/turn) for step response to hold the worst case plasma (β_N=0.3, l_i(3)=1.2, I_p=2 MA, κ=2.0) 2 cm above the midplane and bring it back to the midplane within 200 msec (Fig. 4). The power supply requirement for IRC has been calculated for a high beta plasma (β_N =5.0, li(3)=0.8) undergoing 10% periodic drop in plasma stored energy every 100 msec (Fig. 5). The 10% drop in stored energy is assumed to be the worst recoverable event. The maximum current (voltage) in IRC has been found to be 22 kA-turns (52 V/turn).

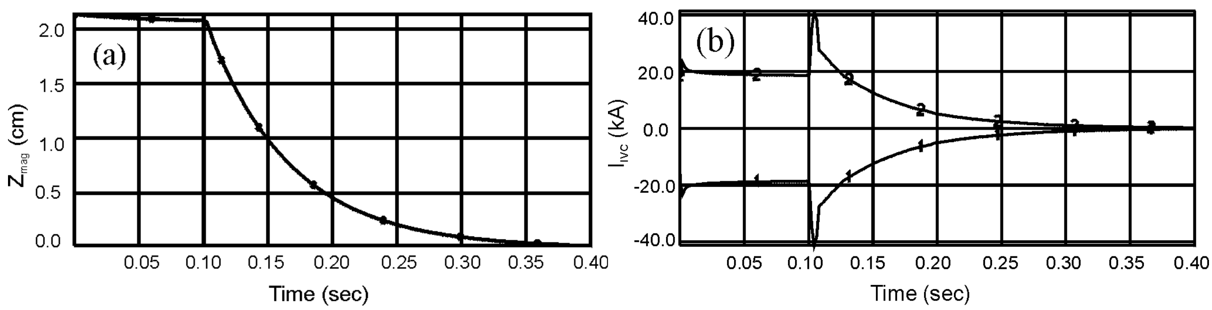

Fig 4. Time histories of (a) Z_{mag} and (b) feedback currents in IVC for 2 cm step response simulation.

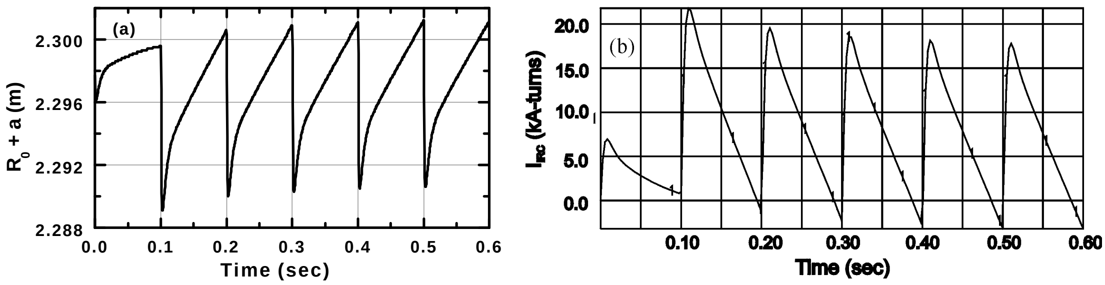

Fig 5. Time histories of R_0+a (R_0=1.8, a=0.5) and feedback currents in IRC for radial position control simulation.

The plasma current and shape control are realized by using seven independent PF coil circuits (11 independent circuits for a single null configuration). A model shape control system for KSTAR has been developed adopting the isoflux control scheme and a standard PID control law. It has been shown that an appropriate weighting factor of PF coils, incorporating the efficacy of each coil to a shape control points, can greatly reduce the feedback currents in PF coils. As a model disturbance to assess the performance of a shape controller, a high β plasma (β_N=5.0) undergoing 20% permanent

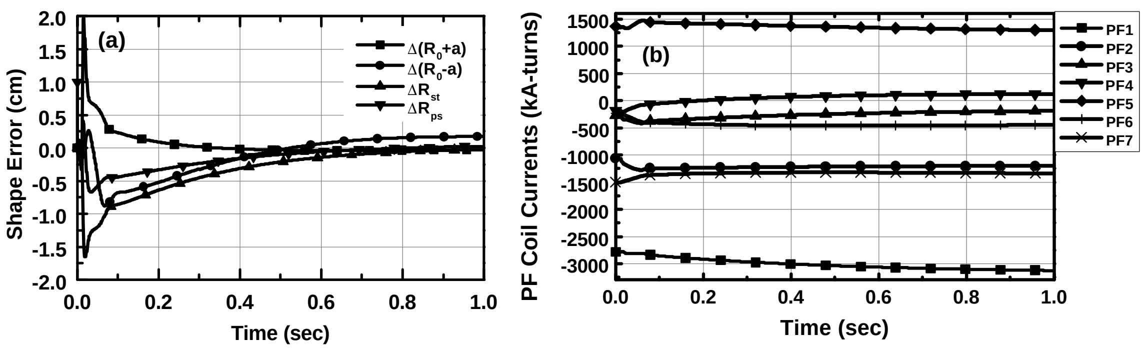

Fig 6. Time histories of (a) shape errors and (b) currents in PF coils during the shape control simulation.

β drop has been considered. Figure 6 shows the time histories of four shape control points [outermost flux surface (R_0+a), innermost flux surface (R_0-a), the nearest point to passive plate (R_p, Z_p), and outer strike point (R_{st}, Z_{st})] and PF coil currents during a shape control simulation.

Both the non-axisymmetric error field compensation (to avoid locked-mode induced disruption) and the control of RWM are realized by utilizing the FEC/RWM coils, which are located inside the vacuum vessel (Fig. 2). In the assessment of possible error fields in KSTAR, various error sources (such as misalignment during coil installation, coil winding error, bus lines, and vacuum vessel weldings have been considered. Figure 7 shows the cumulative probability of (m,n) error field intensity when the permeability of the welded vessel joints is 1.10 and standard deviation of

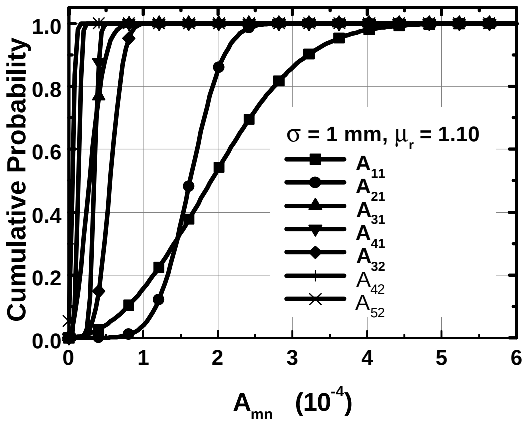

Fig 7. Cumulative probability of normalized (m,n) error field amplitude.

misalignment is 1 mm. It has been shown that the maximum of 20 kA FEC/RWM coil current is required to satisfy the error field tolerance.

The feasibility of using FEC/RWM coils to control RWM has been investigated in a cylindrical geometry. The simple PID control law was used and it has been shown that the RWM can be controlled with large proportional gains. Figure 8 shows (a) the mode structure of (2,1) resistive wall mode, and (b) the growth rate of RWM as a function of proportional gain. With proportional gains larger than 650, the RWM is suppressed and the required feedback coil current is estimated to be about 7.5 kA.

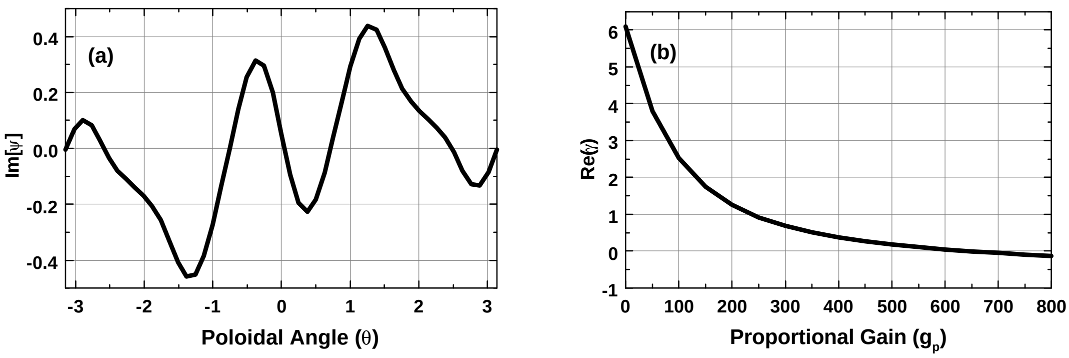

Fig 8. (a) Poloidal mode structure of m=2, n=1 resistive wall mode. (b) Growth rate of resistive wall mode vs. proportional gain.

In the present paper, we summarized the progress in the study of magnetics control in KSTAR. On-going research works include the optimization of plasma initiation process, PF coil power minimization during plasma current and shape control, and the effective coupling of fast and slow time scale control system. The kinetic control issue (both global and local profile control), which is one of the important research goals in KSTAR experiments, is also under investigation.

References

[1] G. S. Lee et al., Nucl. Fusion, Vol. **30**, No. 3Y, p. 576-582.