29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. ***26B****, P-5.084 (2002)*

Detailed Observation of inner Magnetic Field on ATRAS-RFP Experiment

T. Namba, N. Ito, Y. Osanai*, S. Shiina and K. Saito

*Institute of Quantum Science Nihon University, Tokyo 101-8308 Japan:, *Department of Electronics Engineering Tokyo Metropolitan College of Aeronautical, Tokyo 116-0003 Japan*

Radial distributions of inner magnetic field were observed on the equatorial surface and on the line vertical to it by probe-array inserted into discharge tube (major and minor radius 50, 10 cm). The probe-array observes three components of the magnetic field simultaneously at 42 points apart each other by 5 mm with 126 coils and covers the diameter of plasma column. Two type of jacket protecting array from plasma are used, one is made from non-magnetizing stainless steel and the other is quartz with outer diameter of 12 mm and 1 mm thickness, respectively. The skin times of stainless steel jacket to be about 5μs for radial, poloidal and toroidal direction were confirmed by using a test field changing its frequency.

Experimental results

Affects on discharge by insertion of array were examined. The maximum plasma current decrease lineally to the insertion depth of array for the stainless steel jacket, but for the quartz jacket it largely decrease for shallow insertion and then it get loose for deeper insertion as shown in Fig. 1. It may have some relation to the electric field around the reversal surface, but it is not clear yet. From the viewpoint of RFP discharge, pinch and reversal parameter are not affected even by the insertion over plasma diameter, and its values are about 2.2 and –0.4 as well as usually discharge.

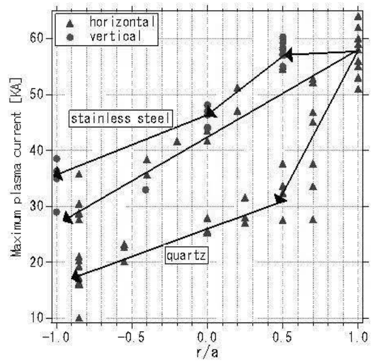

Fig.1 Maximum plasma current vs. insertion depth of magnetic probe array.

Radial distributions of each field component were observed changing the insertion depth of the array by discharges. The results at peak plasma current normalized by it for each discharge are shown in Fig.2. The distributions of toroidal and poloidal field show good coincidence for every shot even for different insertion depth of array so the different value of peak plasma current. But unanticipated radial components were observed as shown in Fig.2(a, b) on the equatorial surface (horizontal) and on the line vertical to it which through the center of discharge tube. These show that the amplitudes are independent on the insertion depth up to a point and change the sign abruptly over the observing region and increase as deeper the insertion beyond the point for stainless steel jacket. This means that magnetic axis change the position to another side of array. These radial components suggest that insertion of array induce m=1 and some times m=2, 3 deformation of the magnetic surface. But when quartz jacket was used, the sign of radial field did not change for all insertion depth, Fig. 2(a).

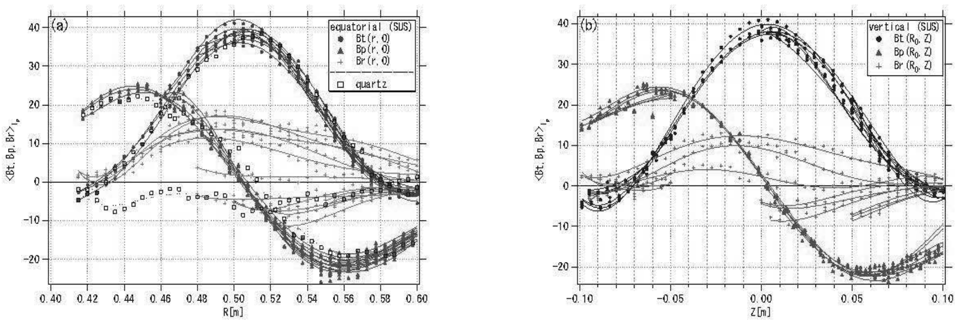

Fig.2 Radial profiles of radial, poloidal and toroidal field component observed on equatorial surface, (a), and on the line vertical to it through the tube axis, (b), by using of magnetic array inserted into plasma with the different insertion depth by discharge.

The radial distributions of magnetic field fluctuation, (dBt/dt, dBp/dt, dBr/dt), are shown with the locus of magnetic axis and reversal surface in Fig. 3 (a), (b), (c), respectively. The fluctuations of each field component have large amplitudes inside the reversal surface, and its phase have radially good coherency over global region.

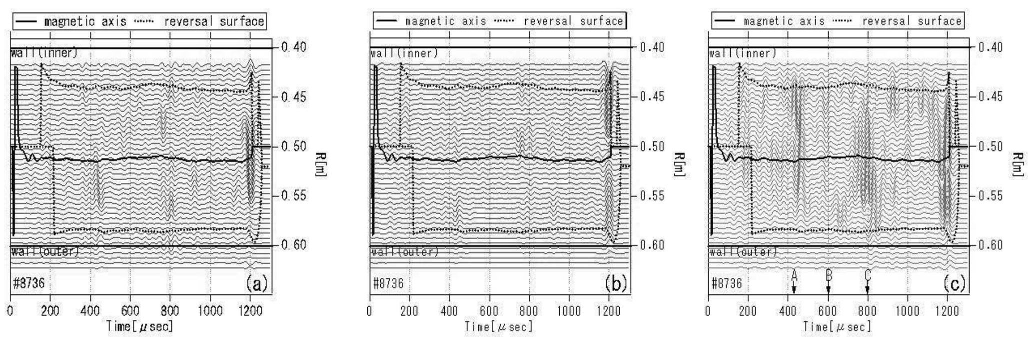

Fig.3 Radial distributions of each magnetic field fluctuations with the locus of magnetic axis and reversal positions of toroidal magnetic field; (a) toroidal,(b) poloidal, and (c) radial fluctuation.

The reversal surfaces were observed at different three poloidal angles separate by 90 degrees on a poloidal cross section by using three magnetic probe arrays inserting 4 cm from plasma surface limited by limiter set at 9cm apart from discharge tube axis. The locus of the center of the reversal surface assumed to be circle is wobbling near the tube axis through a discharge as shown in Fig. 4(top). The radii of the circles are about 8 cm as shown in Fig. 4(bottom). We can see good coherence between the radial fluctuation of center of reversal surface and the fluctuation of magnetic field especially radial field component as shown in Fig.5.

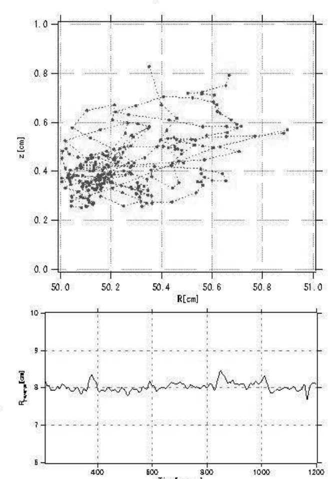

Fig.4 Locus of Center of reversal surface (top) and radius of it, (bottom).

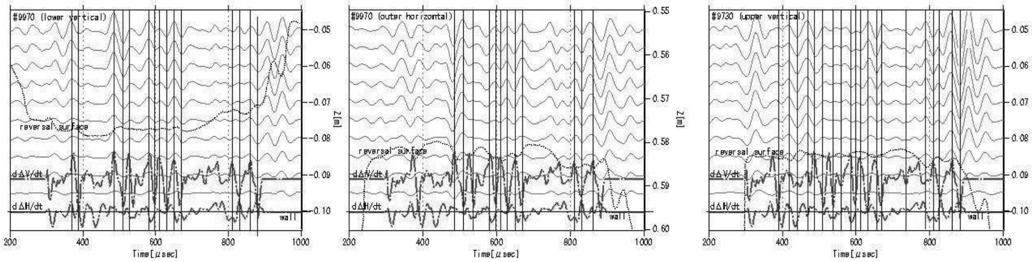

Fig.5 The fluctuation of radial magnetic field observed at different three point separated by 90 degrees on a poloidal section and the fluctuation of center of reversal surface showing strong coherence at large amplitude of fluctuations.

Fig.6 shows inner magnetic field distributions (Bt,Bp,Br) observed at the different toroidal angle by 40 degrees by using of stainless steel and quartz jacket. Especially, the sign of Br observed using quartz jacket is reverse within the entire region of the measurement to that of stainless steel jacket as well as the results obtained using each jacket singly. These results seems suggesting that the direction of shift depend on the material used to jacket, that is conducting or not. The coherency of each field fluctuation is weak in toroidal direction in all observed region.

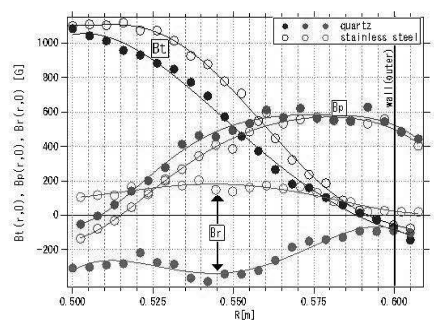

Fig.6 Radial distributions of Br, Bp, Bt at different toroidal angle separated 40 degrees by the two probe arrays.

The toroidal field function is obtained from distribution of toroidal field observed on equatorial surface. The distribution of plasma pressure are calculated from the poloidal and toroidal field observed on equatorial surface neglecting the radial field and assuming cylindrical symmetry. By using these two functions, Grad-Shafranov equilibrium equation were numerically solved and the result are shown in Fig.7. Contribution of bootstrap and Pfirsch-Schlüter currents estimated from the analysis are several percent to the total current and latter is one order smaller than former.

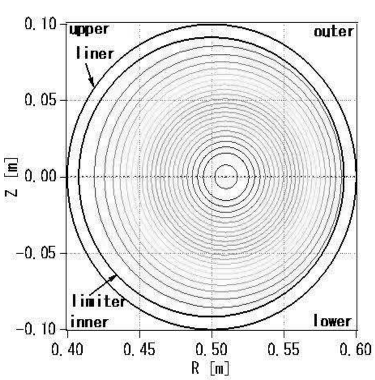

Fig.7 Equilibrium magnetic surface calculated by using of observed magnetic field

Conclusive discussions

The fluctuations of each field component have large amplitudes inside the reversal surface, and its phase have radially good coherency over global region. The locus of the center of the reversal surface is wobbling near the tube axis through a discharge and its radial fluctuations have good coherence to the fluctuation of radial magnetic field. These are suggesting that the high n kink mode having the resonant surface near the reversal surface is wobbling with small amplitude and making the source of the α dynamo, because the effect proportional to $-\tilde{\mathbf{u}}\cdot(\nabla\times\tilde{\mathbf{u}})\tau/3$, where $\tilde{\mathbf{u}}$ is the turbulent velocity and τ the typical period existing of $\tilde{\mathbf{u}}$.

The radial distribution profiles of toroidal and poloidal field are independent on value of plasma current and are not influenced by the shift of magnetic axis seriously. But radial components are sensitive to the shift of magnetic axis, m=1 and deformation of magnetic surface, m=2,3. Almost part of radial field are explained by the m=1 kink mode as shown in Fig. 8, where dotted line show the calculated contribution of the poloidal field to the probe as

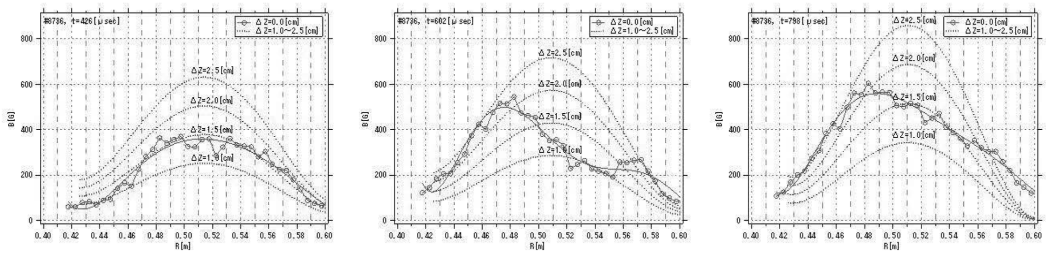

Fig.8 Radial profile of observed radial magnetic field compared calculated one as a contribution of the poloidal field by the shift of magnetic axis.

radial component of the field by the shift of magnetic axis with different quantities of the shift, that are 1.0, 1.5, 2.0 and 2.5 cm, respectively. Fig.8 (left) shows that calculated profile has good coincidence to the experimental result at shift of 1.5 cm, but radial field profiles seen in (center) and (right) show that these are not explained only by a shift. We must consider other contributions for example m=2, 3 deformation of the magnetic surface. Moreover, in large fluctuation period of radial field denoted by sign A, B, C in Fig. 3(c), the radial profiles of radial field component shown Fig. 9 (left and center) suggest appearance of m=3 mode probably and not reconnection of magnetic field line. Because, poloidal field profiles do not show the sign of the appearance of two magnetic axis suggesting existence of bifurcation of magnetic surface as seen in Fig. 9 (right).

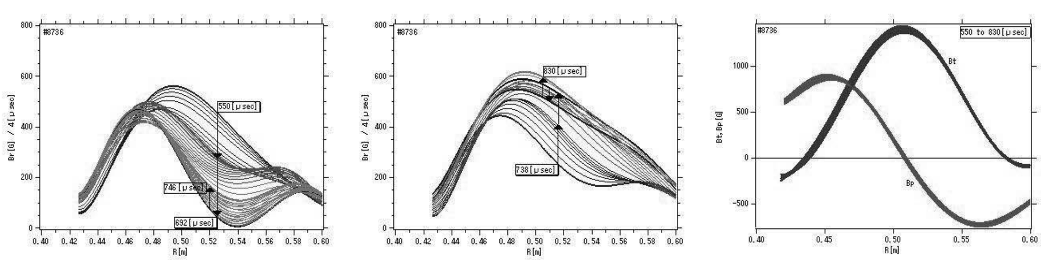

Fig. 9 Time history of radial distribution of radial field (left and center) in the period denoted A, B, C in Fig. 3, and the radial distribution of the poloidal and toroidal field (right) observed during the three period A, B, C.