

Effects of an oscillating toroidal electric field in the RFP plasma

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1. Introduction and Experimental Set-up

Reversed field pinch (RFP) plasma is one of the axisymmetric toroidal confinement plasmas for a nuclear fusion reactor. The configuration is characterized by the reversal of the toroidal magnetic field on the plasma edge. This reversal of the toroidal magnetic field makes RFP plasma a high β confinement because of the high magnetic shear. Dynamo activity is an essential role in the plasma formation and sustainment. In a general RFP, a toroidal loop voltage generates the toroidal plasma current. The poloidal plasma current is, however, not driven inductively, and it is generated through a dynamo activity. Thus the RFP configuration is self-organized by the dynamo activity and the direction of the plasma current density

becomes parallel to that of the magnetic field spontaneously.

We describe an experimental study of self-organization processes with dynamo activity in RFP plasma. To investigate the behavior of the dynamo activity, the oscillating toroidal electric field (perturbation) was applied to the standard RFP plasma. These experimental studies were performed on the

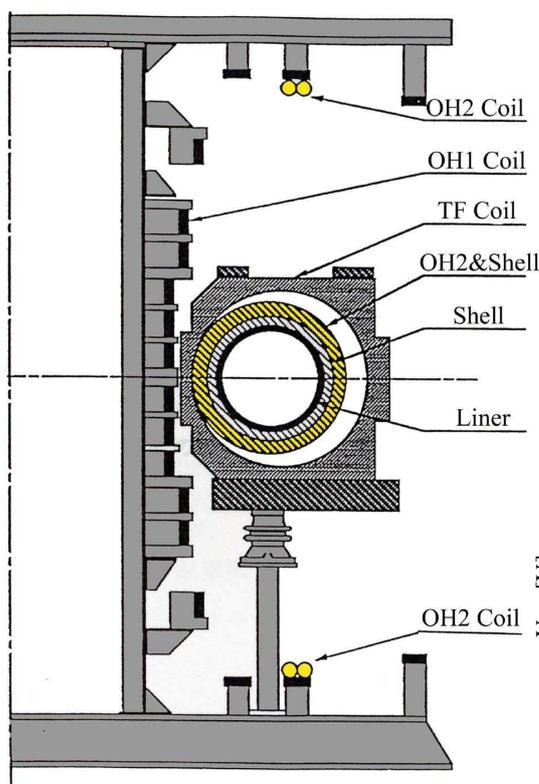


Fig 1: Poloidal cross-section of the ATRAS-RFP device. Major and minor radii are 0.5m and 0.09m respectively.

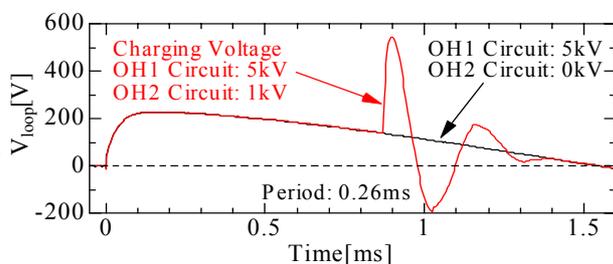


Fig 2: Time development of the toroidal loop voltage with (red line) and without (black line) the OH2 circuit. OH2 is the additional circuit for the oscillating toroidal electric field.

ATRAS RFP plasma at the Nihon University. ATRAS is a middle size RFP device with major and minor radii of $R=0.5$ m and $a=0.09$ m, respectively. Typical parameters of ATARS RFP plasma are plasma current of 60kA, pinch parameter of 2.1, reversal parameter of -0.5, and discharge duration time of approximately 1.6ms. Figure 1 shows the poloidal cross section of the ATRAS device. There are two ohmic heating coils (OH1+OH2) in ATRAS device. The additionally ohmic heating coil (OH2) is the characteristic point of the ATRAS RFP researches. The OH2 circuit can operate independently of OH1 circuit and can perturb the RFP plasma during the discharge. Figure 2 shows the typical waveform of the toroidal loop voltage in a vacuum with (red line) and without (black line) the oscillating toroidal electric field, respectively. The period of the OH2 circuit is variable and the shortest period is approximately 0.26ms as shown in Fig.2.

2. Experimental Results

Figure 3 shows the typical waveform of the RFP discharge with (red lines) and without (black lines) the oscillating toroidal loop voltage, respectively. The toroidal plasma current I_p , the toroidal loop voltage V_{loop} , the averaged toroidal magnetic field $\langle B_t \rangle$, the toroidal magnetic field at the plasma edge B_{tw} , the pinch parameter Θ , the reversal parameter F and $\Theta/(1-F)$ are shown in Fig.3. The reversal and pinch parameters are estimated by the edge toroidal and poloidal magnetic fields normalized by the averaged toroidal magnetic field. In this experiment, the standard RFP configuration was set up initially and the OH2 circuit oscillates the toroidal loop voltage at $t=0.85$ ms. We can see that the toroidal plasma current is oscillated by the oscillating toroidal loop voltage as

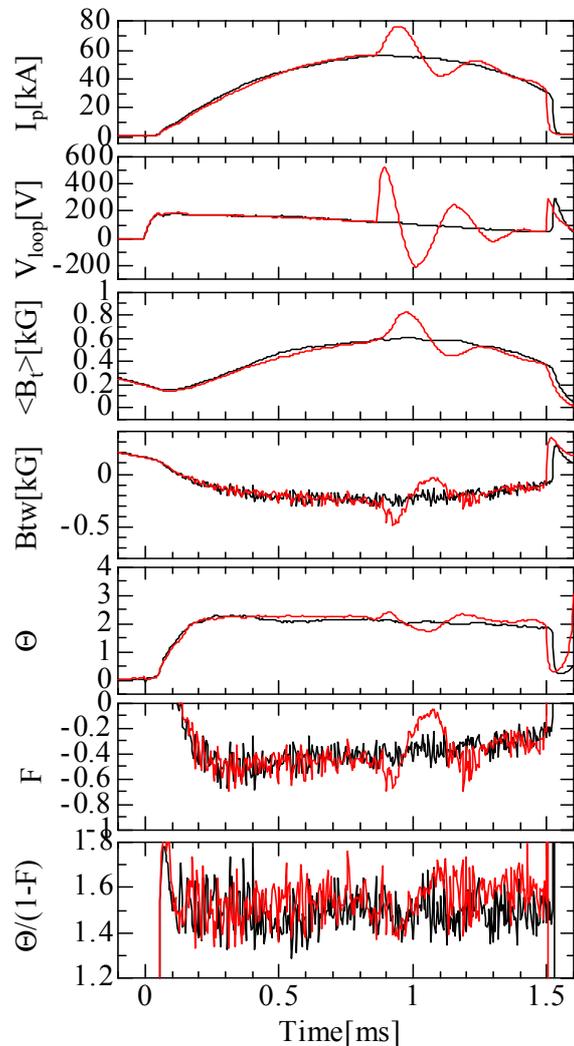


Fig.3: Time evolution of the RFP discharge with (red lines) and without (black lines) the oscillating of the toroidal electric field.

shown in Fig.3. The half period of the toroidal plasma current is approximately 0.15 ms. Interesting responses of plasma parameters were observed with the oscillating toroidal plasma current. One of the responses was the oscillation of the averaged toroidal magnetic field. The averaged toroidal magnetic field is oscillated by the oscillation of the toroidal plasma current. Figure 4

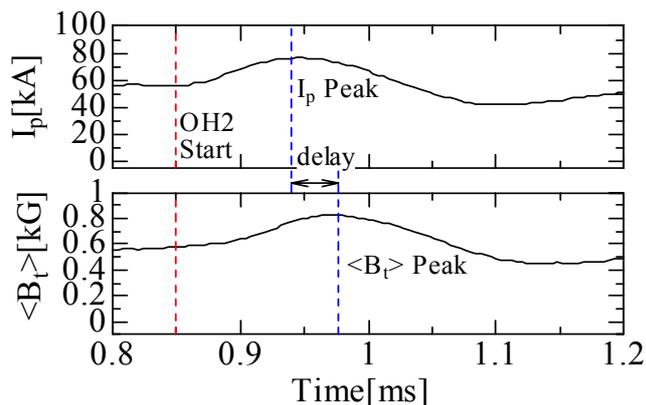


Fig.4: Time evolution of the toroidal plasma current and the averaged toroidal magnetic field. The delay time is approximately 30 μ s.

shows the time evolution of the toroidal plasma current and the averaged toroidal magnetic field. It is obvious that there is a time lag between them. Consequently, the F and Θ values also change during the oscillation of the toroidal plasma current as shown in Fig. 3.

To get the information on the internal structure of the magnetic fields, the magnetic probe arrays were inserted into the RFP plasma. The directions of the magnetic probe arrays are toroidal, poloidal and radial and each magnetic probe array consists with 42 probes at equal intervals of 5mm. The magnetic probe arrays are covered by stainless steel. Figure 5 shows the time evolution of the toroidal plasma current and the toroidal loop voltage with the insertion of the magnetic probe array. The insert of the magnetic probe array makes plasma current and discharge duration time short. The F and Θ values are, however, almost constant at the 2.1 and -0.5 with and without the insert ion of the magnetic probe arrays [1]. Figure 6 shows the contour plots of the poloidal and toroidal magnetic fields with the oscillating loop voltage. The current density profiles were estimated by the distributions of the internal magnetic fields. The contour plots of the toroidal and poloidal current density profiles are shown in Fig.7.

3. Discussions and Conclusion

To investigate the dynamo activity in RFP plasma, the oscillating loop voltage was applied during the discharge. In this experiment, the toroidal magnetic field was oscillated by the oscillating toroidal plasma current. The value of $\Theta/(1-F)$, which is the index of the generation of the toroidal magnetic field by the toroidal plasma current, is not constant in the oscillation.

In addition, there is a time lag between the toroidal plasma current and the averaged toroidal magnetic field in the oscillation. This result implies that the changing time of the toroidal current density will be faster than the relaxation time of the dynamo process.

To get the information on the internal distributions of the magnetic fields and the plasma current densities, the magnetic probe arrays were inserted into the RFP plasma. In this experiment, the toroidal plasma current density increases at the central part of the plasma column because almost of the magnetic field line near the plasma edge is poloidal direction and the temperature at the plasma edge will be low. Due to the increase of the toroidal current density at the central part, the poloidal magnetic field increases outside of the increasing toroidal current density. The poloidal current density also increases at the same position of the increase of the poloidal magnetic field. As a result, the toroidal magnetic field at the central part increases due to the solenoidal effect.

[1] T. Namba, *et al.*, in the CDROM at 30th EPS conference.

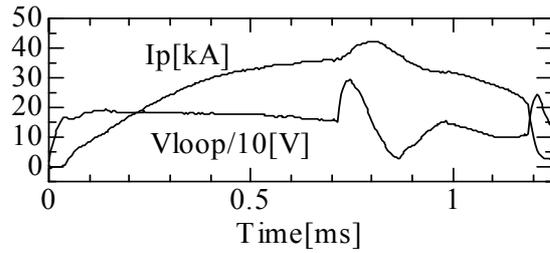


Fig.5: Time evolution of the RFP discharge with the insertion of the magnetic probe array

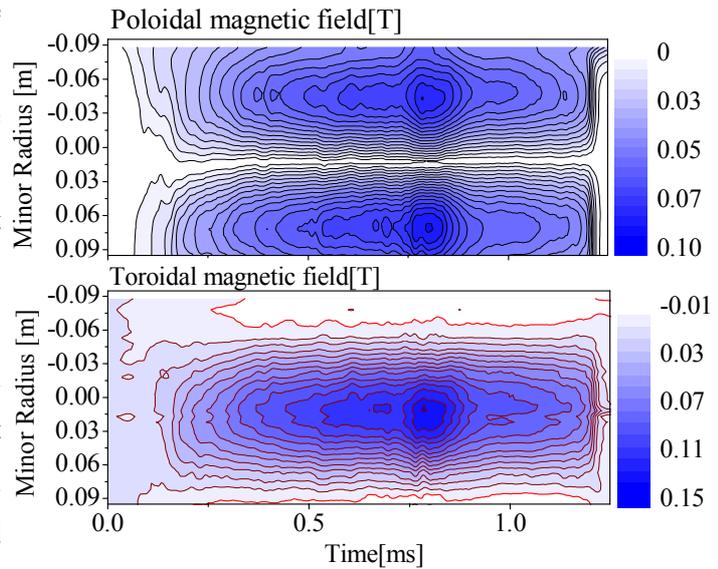


Fig.6: Contour plots of the poloidal and toroidal magnetic fields with the oscillating toroidal loop voltage.

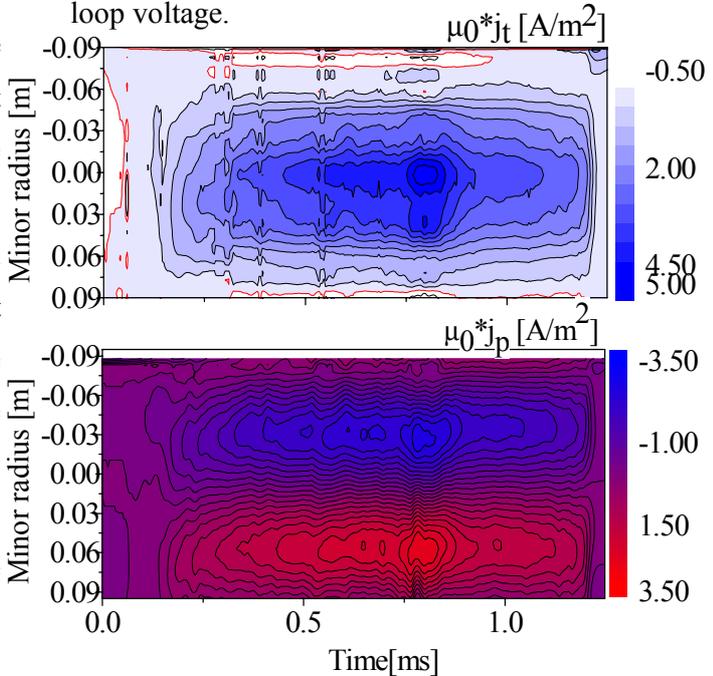


Fig.7: Contour plots of the poloidal and toroidal current density profiles with the oscillating toroidal loop voltage.