Rapid Communications

Plasma Current Start-up by ECW and Vertical Field in the TST-2 Spherical Tokamak

MITARAI Osamu[1)], TAKASE Yuichi[2)], EJIRI Akira[2)], SHIRAIWA Syunichi[2)], KASAHARA Hiroshi[2)], YAMADA Takuma[2)], OHARA Shinya[2)], TST-2 Team[2)], NAKAMURA Kazuo[3)], IYOMASA Atsuhiro[3)], HASEGAWA Makoto[3)], IDEI Hiroshi[3)], SAKAMOTO Mizuki[3)], HANADA Kazuaki[3)], SATOH Kohnosuke[3)], ZUSHI Hideki[3)], TRIAM Group[3)] and NISHINO Nobuhiro[4)]

[1)]*Institute of Industrial Science and Technical Research, Kyushu Tokai University, 9-1-1 Toroku, Kumamoto 862-8652, Japan*

[2)]*Grad. School of Frontier Sciences and Grad. School of Science, Univ. Tokyo, Kashiwa 277-85611, Japan*

[3)]*Research Institute for Applied Mechanics, Kyushu University, 6-1 Kasugakoen Kasuga, 816-8580 Japan*

[4)]*Department of Engineering, Hiroshima Univ., Higashi-Hiroshima 739-8527, Japan*

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Plasma current start-up and ramp-up to 10 kA have been demonstrated in the TST-2 spherical tokamak without the use of the central solenoid. Only the electron cyclotron wave (ECW) and the outer equilibrium field coils are used. The plasma current evolution depends on the poloidal coil arrangement. It is also demonstrated that the plasma current start-up can take place without the field null.

Keywords:

spherical tokamak, current start-up, central solenoid, ECW, vertical field

Plasma current ramp-up has been recognized as a major difficulty in low aspect ratio spherical tokamaks [1] due to insufficient room for the central solenoid (CS) on the inboard side of the torus. A new concept has been proposed for ramping up the plasma current using the vertical field and heating power [2,3], and was successfully demonstrated on the JT-60U tokamak [4-6]. However, in the JT-60U experiment, the inboard turns of the triangularity control coil acted as a part of the CS and contributed 20% of the total flux. While the vertical field effect on plasma current ramp-up has also been demonstrated in a recent MAST experiment [7], such a result was obtained by a rapid ramp of special induction coils located inside the vacuum chamber (not by a slow ramp of the usual vertical field coils). In this paper we report the first experimental demonstration of plasma current start-up by the outer vertical field coils alone with ionization provided by ECW in the TST-2 spherical tokamak without the use of the central solenoid.

In the present experiment, PF2, PF3, and PF5 coils (shown in Fig. 1) were used. Two sets of poloidal field coil arrangements were used: (1) PF2 and PF5 connected in series with a uni-polar power source and PF3 coil with a bi-polar power source, and (2) PF2 with a bi-polar power source and PF3 with a uni-polar power source.

The launcher for ECW, designed for electron Bernstein wave (EBW) heating, at a frequency of 8.2 GHz is installed on the outboard side of the torus, below the midplane. The cut-off density for the O-mode is 0.83×10^{18} m^{-3}. In TST-2, the major radius is $R \leq 0.38$ m, the minor radius is $a \leq 0.25$ m, the elongation can be $\kappa \leq 1.8$, and the toroidal field is $B_t \leq 0.3$ T. The diagnostics available for this experiment were quite limited.

The plasma current evolution (#302405) using the first coil arrangement is shown in Fig. 2. The initially positive PF3 coil current (creating an opposite vertical field) is reduced at 0.138 s and increases in the negative direction to provide the flux and the equilibrium field. The current through PF2 and PF5 coils starts at 0.142 s when the PF3 current has reached a plateau level. The plasma current starts at t = 0.139 s around the time I_{PF3} crosses zero, reaches 10 kA at 0.143 s, and then

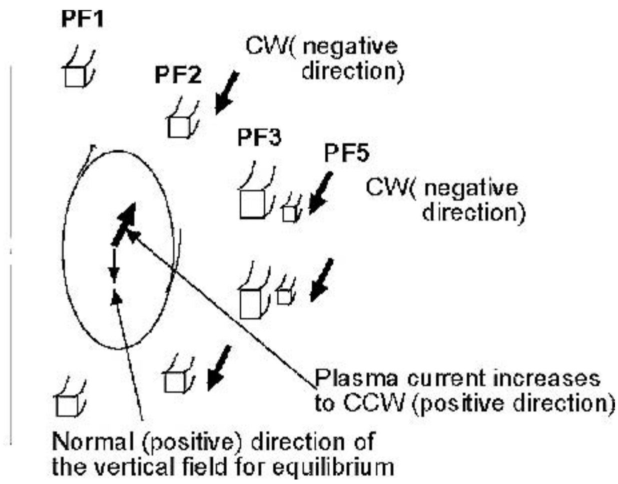

Fig. 1 Schematic of the TST-2 plasma cross section and poloidal field coils.

author's e-mail: omitarai@ktmail.ktokai-u.ac.jp

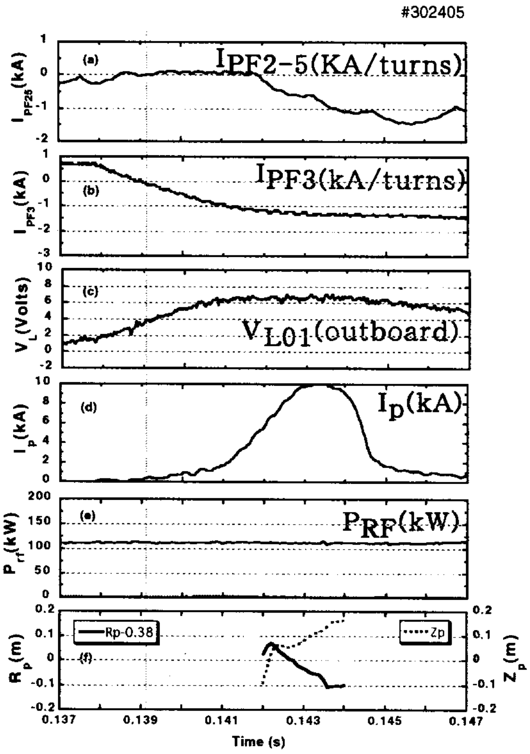

Fig. 2 Plasma current start-up in TST-2 at B_t=0.28 T with the first coil arrangement, with (a) PF2 and PF5 coil current (connected in series), (b) PF3 coil current, (c) loop voltage measured on the outboard side of the torus, (d) plasma current, (e) injected and reflected RF powers, and (f) horizontal and vertical positions of the plasma current centroid. The current start-up time is indicated by the vertical line.

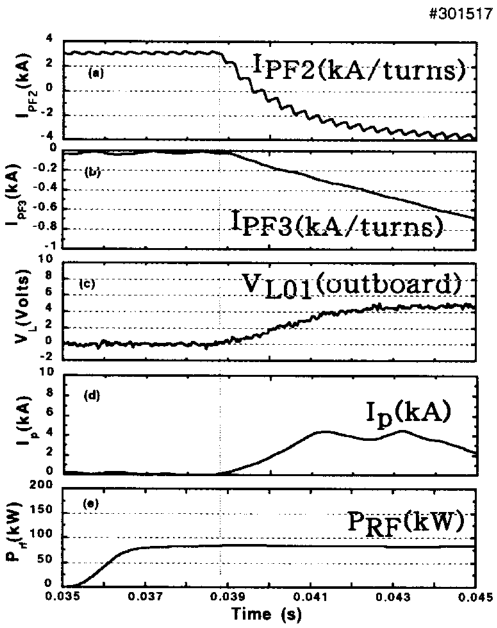

Fig. 3 Plasma current start-up with the second coil arrangement. The elements are the same as Fig. 2 except for PF2 coil current.

decays. The plasma position was deduced using a variable current filament model, in which the plasma current is represented by a single filament and its location was adjusted to fit the magnetic measurements. Near the peak of the plasma current, the plasma position is located near the center of the vacuum vessel at R = 0.38 m, and ~ 6 cm above the mid-plane. The plasma then moves inward and upward. The breakdown timing is less reproducible in this coil arrangement. In some cases the plasma current starts when I_{PF3} crosses zero as shown here, but it sometimes starts before I_{PF3} reversal.

A typical plasma current evolution (#301517) for the second coil arrangement is shown in Fig. 3. The plasma current starts while the vertical field is clearly negative, reaches ~ 5 kA, and is maintained at approximately this level for 2 ms. The breakdown timing is quite reproducible. The value of the opposite vertical field at current start-up varied in the range $[B_V]_{START}$ ~ –40 to –60 G over 24 shots.

We have demonstrated for the first time that plasma current start-up and ramp-up is possible using ECW and the outer vertical field coils alone in an ST and that a field null is not necessary when a powerful ionization source exists. These results imply the possibility of a central solenoid-free current start-up in a future ST reactor.

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