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Tokamak discharges and magnetic field configuration in TOKASTAR-2 device

TOKASTAR-2装置におけるトカマク放電と磁場配位

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The small device named TOKASTAR-2 is operated to generate tokamak and helical configurations independently with tokamak-helical hybrid coils. Presently, we plan to install additional field coils to generate vacuum magnetic surface without plasma current. By the magnetic field line tracing analysis, the setup angle of additional field coil was decided. In tokamak experiments, the vertical displacement of plasma was observed. To suppress this displacement, a conductive shell was installed. Plasma current increased slightly. However, measured plasma current was still far smaller than design value of the device. Then we plan to construct a new pair of pulsed vertical field coils installed inside the vacuum chamber.

1. Introduction

Tokamak and helical systems have been widely investigated as efficient toroidal magnetic plasma confinement devices. Both systems have unique merits and demerits. TOKASTAR configuration [1] is one of compact tokamak-helical hybrid confinement systems. A new small device (R~10cm) named TOKASTAR-2 is designed to generate tokamak and helical configurations independently by different type of coils.

One of main purposes of this device is to investigate the effects of outer helical application on tokamak plasmas, especially, to suppress plasma current disruption. Other purpose is to generate current-less helical plasma, and confirm that plasma current effects in the helical system when the plasma current is induced.

Figure 1 shows the coil configuration of TOKASTAR-2 device. Present TOKASTAR-2 is composed of four kinds of coil systems; eight toroidal field (TF) coils, three ohmic heating (OH) coils, a pair of vertical field (VF) coils and a pair of helical field (HF) coils. All coil systems except VF coils are installed inside the vacuum chamber.

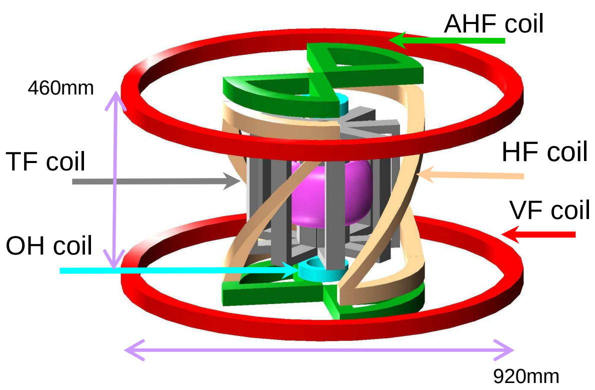

Fig.1. Coil configuration of TOKASTAR-2

2. Helical configuration

Present coil systems of TOKASTAR-2 without additional helical field (AHF) coils cannot form the vacuum magnetic surface. We plan to install two pair of AHF coils to generate vacuum magnetic surfaces[2]. The AHF coils are located on the upper or lower side of the arcs of HF coil as shown in Fig.1. However, if particular setup angle is assumed in

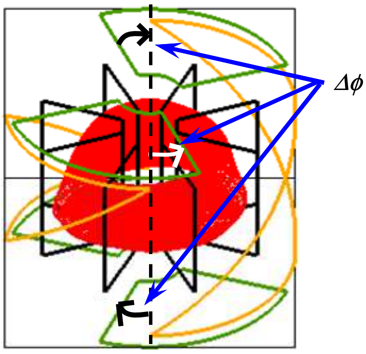

Fig.2. Setup angle of AHF coil $\Delta\phi$.

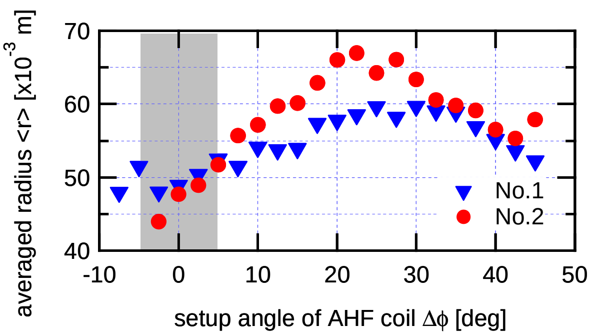

Fig.3. Averaged radius vs. $\Delta\phi$.

toroidal direction, the AHF coil interferes with measurement probes.

Here, we estimated the effect of the setup angle of AHF coils. The setup angle $\Delta\phi$ is defined that the angle by which AHF coils are rotated in toroidal direction as shown in Fig.2. Magnetic confinement field line, TF coil, HF coil and AHF coil are indicated by red, black, yellow and green lines, respectively.

The simulation was carried out using two coil current ratio patterns shown in Table I. Averaged radius

Table I. Coil current ratios used in simulations of Fig.3.

	I_{AHF}/I_{HF}	I_{TF}/I_{HF}	I_{VF}/I_{HF}
No.1	1.4	0.86	0.14
No.2	1.5	0.62	0.12

as a function of setup angle $\Delta\phi$ is shown in Fig.3. The shadow area in Fig.3 indicates the toroidal angle where the AHF coil interferes measurement probes. Averaged radii in the region where $\Delta\phi$ is 15~40 deg are greater than these in the region where $\Delta\phi$ ~0deg. From this result and consideration of setup supporting structures for AHF coils, we decided to construct the AHF coils at $\Delta\phi$=22.5deg.

3. Trial of tokamak discharge

We have been trying to induce the plasma current using OH coil and static VF coil systems. Pre-ionized plasma was generated by electron cyclotron resonance (toroidal field: 0.0785T at R~10cm and radio frequency wave: 2.45GHz). About 4V loop voltage and static 15G vertical field were applied to the pre-ionized plasma. However, the plasma current was obtained only 90A. Additionally, a vertical displacement was observed by a fast camera (20500fps). Figures 4(a)~(d) show successive photographs of tokamak discharge taken by the fast camera. Each photograph displays the area between 6 and 8cm in R direction and between -1 and 1cm in Z direction. OH plasma moved vertically upward shown in Fig.4. It is supposed that the displacement is due to up-down unbalance of eddy currents induced in vacuum chamber and applied static vertical field. And the error field made by OH coils keeps N value negative, which might be another reasons of the displacement.

Then we installed a conductive shell to suppress the vertical displacement and to increase the plasma current. Figure 5 shows the dependence of plasma current on helium gas pressure P_{He} with/without the conductive shell. Plasma current with the shell increased by about 40A compared with the case

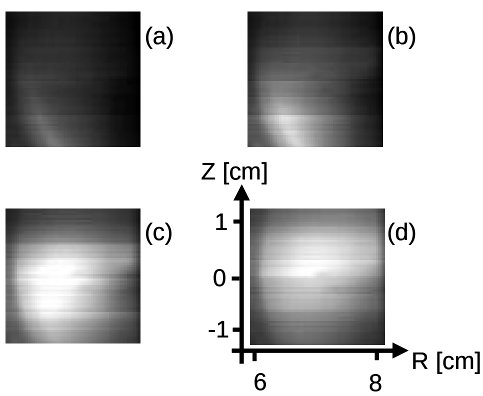

Fig.4. Successive photographs of tokamak discharge taken by fast camera. Time interval is 24.7µs. Photograph (c) corresponds to the plasma current maximum.

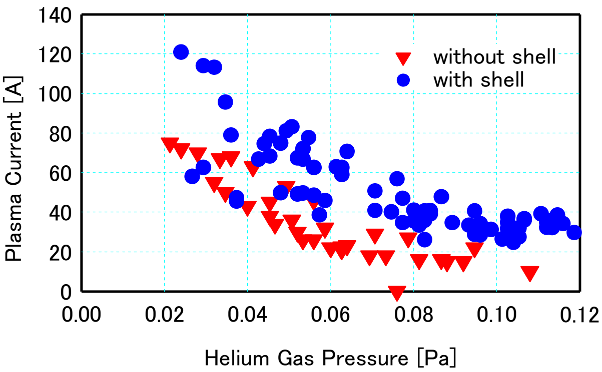

Fig.5. Plasma current vs. helium gas pressure with/without conductive shell.

without the shell at P_{He}~0.02Pa. The effect of suppressing the vertical movement will be confirmed experimentally in the near future.

Although plasma current increased by installing the conductive shell, it was not a drastic increase. We plan to construct a new pair of VF coils which is installed inside the vacuum chamber and has appropriate inductance for pulse discharge system.

References

[1] K.Yamazaki and Y.Abe, Nagoya Reseach Report IPPJ-718 (1985).

[2] T. Oishi, *et al.*: *Proc. 23th IAEA Fusion Energy Conference, Daejeon,2010* ICC/P5-04