§25. Optimization of Coil Sets for Steady State Helical Fusion Reactors

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For steady state helical fusion reactors, it is important to achieve a good balance between the blanket space (the most narrow space between the chaotic field lines and the inner wall of the helical coils) and plasma volume. We have analyzed numerically the magnetic configuration produced by the helical coils winding along a geodesic line of a torus, which we call the torus as "winding frame" for the helical coils. Furthermore, performance of DT alpha particle confinement is strongly improved by increase of the elongation factor of the cross-section of winding frame for the helical coils [1)].

In order to express the various types of winding frames with only a few parameters (a_1, a_2, a_3), we have developed the following form for the cross-section of the winding frame

$$
\begin{aligned}
\chi &: \text{ poloidal angle} \\
R_0 &: \text{ major radius of the helical coil} \\
a_c &: \text{ minor radius of the helical coil} \\
r - R_0 &= a_c \times \frac{a_1}{1 - a_2 \cos\chi} \cos\chi \qquad (1) \\
z &= a_c \times a_3 \sin\chi \qquad (2)
\end{aligned}
$$

where r and z are the standard cylindrical coordinates.

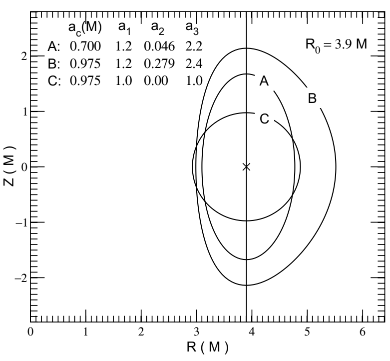

Fig. 1: "C" is the winding frame of the LHD helical coils.

Figure 1 shows the examples of the D-shaped winding frame, including the winding frame of the LHD. An example of assembly of helical coils, the vertical magnetic field coils, and the vacuum vessel is shown in Fig. 2. The winding frame of the helical coils is shown by "A" in Fig. 1. Structure of the magnetic surface is shown in Fig. 3. A combination of the geodesic winding D-shaped magnetic field and optimized setup of vertical magnetic field coils brings a large plasma volume in reduced-size helical reactor. Confinement improvement due to large plasma volume and plasma current driven by magnetic axis shift make fusion ignition possible, with $R_0 = 12\,\mathrm{m}$ and $B_{\mathrm{ax}} = 8\mathrm{T}$, and $V_{\mathrm{lcfs}} = 2048.5\,\mathrm{m}^3$.

Fig. 2: Assembly of helical coils, vertical magnetic field coils, and vacuum vessel.

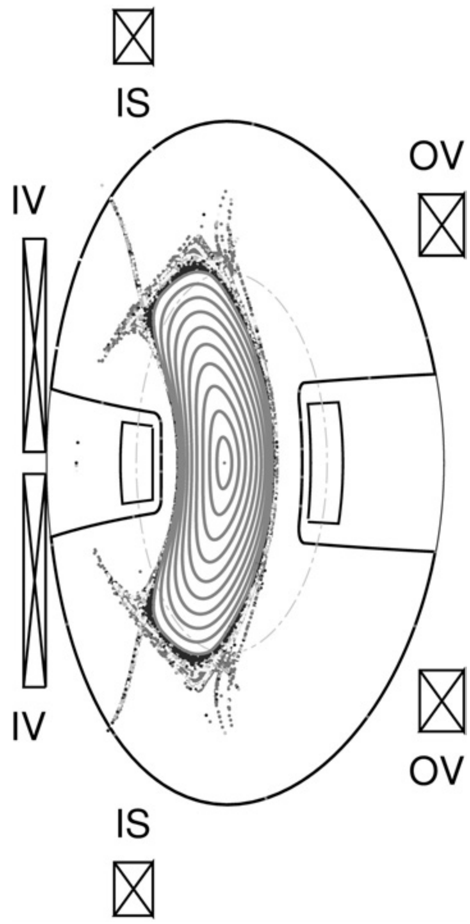

Fig. 3: Cross sections of magnetic surface, helical coils, poloidal coils (IV, IS, OV) and vacuum vessel.

1) T.Watanabe, Reduced-Size LHD-Type Fusion Reactor with D-Shaped Magnetic Surface , (PFR. 7, 2403113-1-5 (2012)).