§7. Design Studies on High-Temperature Superconducting Coil Option for FFHR

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The conceptual design studies on the heliotron-type fusion energy reactor FFHR are being conducted on both physics and engineering issues [1]. The present design gives a major radius of 14-18 m with a toroidal magnetic field of 6-4 T in order to generate ~3 GW of fusion power. The stored magnetic energy of the superconducting coil system should be in the range of 120-150 GJ. We propose that helical coils of a continuous manner and a huge size as FFHR be constructed by prefabricating half-pitch segments with high-temperature superconductors (HTS); the segments are then jointed on site. The concept is illustrated in Fig. 1(a). By employing HTS, joule heating at a number of joint sections could be accepted with elevated temperature operations (at 20-30 K). We consider "REBCO coated-conductors", such as YBCO and/or GdBCO, to be a good candidate according to the recent development of wire production technology. Fig. 1(b) shows an example of the HTS conductor design, which has a nominal current of 100 kA at a maximum magnetic field of 13 T. We have successfully carried out a proof-of-principle experiment of HTS conductors with 15 kA critical current at 8 T and 20 K [2]. It was confirmed that the stability margin is about two orders of magnitude higher than that of low-temperature superconductors (LTS).

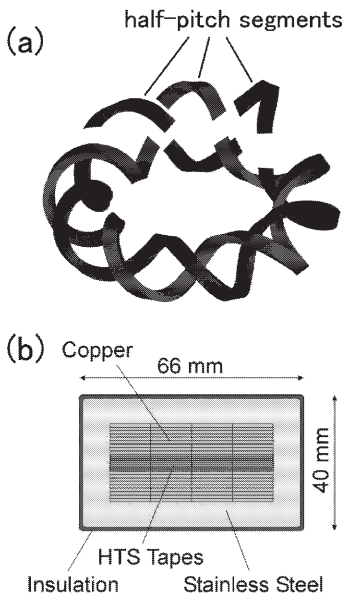

Fig. 1 (a) A segmented-type fabrication of helical coils and (b) a conceptual design of HTS superconductor.

One of the concerns in applying HTS conductors is that relatively large shielding currents would be generated, since the HTS tapes are used in the conductor shown in Fig. 1 without having twisting and transpositions. Thus, the shielding currents may distort the magnetic surfaces. In order to investigate this effect, we model the shielding currents in the helical coils and try to see their effects on the vacuum magnetic surfaces. Presently, the shielding currents are assumed to be flowing in two thin plates located at the side edges of the helical coils and the return path is taken uniformly in the cross-sectional area. Comparison of the vacuum magnetic surfaces with and without having shielding currents are shown in Fig. 2 for the design of FFHR-2m2 Type-A. It seems that the effect of shielding currents is not significant even though the present model gives almost full shielding of the radial magnetic field inside the helical coils. In reality, the shielding current should be much lower with finite critical current density. Thus, we now consider that the application of HTS conductors is feasible for heliotron fusion reactors.

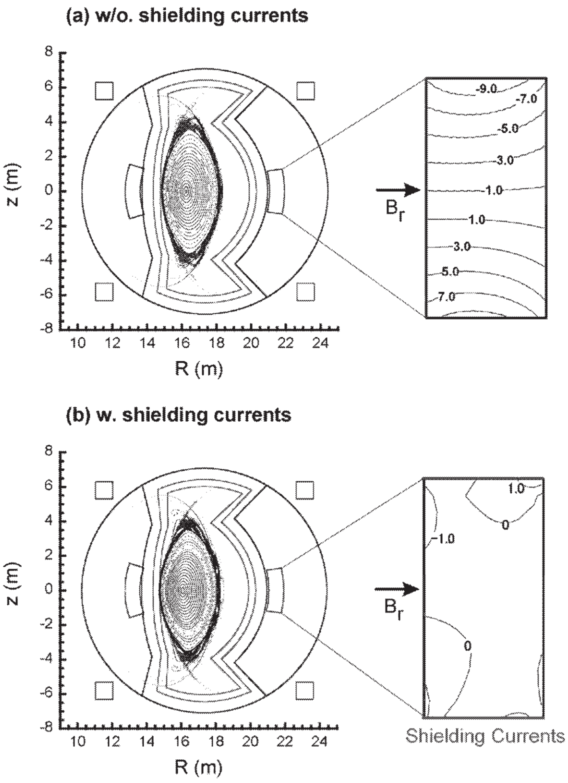

Fig. 2 Comparison of vacuum magnetic surfaces with and without shielding currents in the helical coils. Spatial distribution of the radial magnetic field is shown in the cross-section of a helical coil.

1) Sagara, A., et al., Fusion Eng. Des. 81 (2006) 2703.
2) Bansal, G. et al., Plasma and Fusion Research 3(2008) S1049.